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## Original Communications

### TRACHEAL RECONSTRUCTION


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GLUCK and Zeller[1] are credited with the first investigations concerning tracheal reconstruction. The tracheal rings of dogs were severed and anastomosed successfully. In 1884,[1] Kuester removed a stricture of the human trachea and repaired the defect successfully. During the latter part of the nineteenth and early twentieth centuries, secondary closure of tracheostomies was often required in patients who had survived diphtheria and required tracheostomy as a lifesaving measure.[1] Various methods were utilized; fascia or skin flaps were often used, as well as supporting cartilaginous grafts and metallic prostheses.

It has been established that in most cases early approximation of an incised trachea will be successful. Nach and Rothman[2] describe primary suture of the trachea after knife wounds with satisfactory results. Successful reanastomosis of the cervical trachea, after division and resection in dogs, has been recorded by Maisel and Dingwall.[3] In some instances, segments as large as 2.5 cm. were removed. In a series of 12 animals, there was one instance of postoperative stenosis. Ferguson and his associates,[1] in the study of primary tracheal anastomosis, concluded that when stenosis, following repair, did not exceed one third of the original lumen, there were no distressing symptoms. If, however, the stenosis occluded the trachea to one fourth of its normal circumference, stridor and respiratory infection would follow.

Large defects of the trachea, involving substantial loss of tissue, sometimes preclude primary end-to-end anastomosis. Ferguson found that in dogs, if


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tension was sustained on the severed ends, some length could be added, particularly if the procedure was done in stages. This technique, however, does not appear to be applicable in the human being.

The feasibility of primary suture of the trachea or bronchi has been established both experimentally and by clinical experience. The contributions of Paulson and Shaw,[4] Abbott[5] and Bikfalvi[6] and their co-workers, in excising stenosed portions of the tracheobronchial tree and reanastomosing to conserve lung tissue, have been of great importance. Scott's[7] case of primary suture of the trachea, following laceration by a broken windshield, is important since the patient was living and well three years after surgical repair and, although the trachea had been completely severed, there was no abolition of the cough reflex.

Large tracheal defects with circumferential loss of tissue present a more difficult problem and must be repaired with some material which will be airtight, semirigid, and not be rejected by the body. Combinations of cartilage, skin grafts, and fascia have been used successfully in small defects but are rarely adequate when the defect is large.

Gebauer[8] has made many important contributions in the use of reinforced dermal grafts to replace small stenotic lesions of the membranous portion of the bronchus. Penton and Brantigan[9] have employed viable pedicle flaps to cover larger defects, and Gibbon[10] has used a portion of costal cartilage wrapped in pleura for the same purpose.

A great variety of prostheses have been studied for the repair of tracheal defects. Daniel's[11] investigations proved that tubes of Vitallium, stainless steel, and glass would temporarily provide an airway. Longmire[12] has reported the use of a Lucite tube joined to the tracheostomy tube. This prosthesis was removed ten and one half months later. The airway did not remain patent, however, and it was necessary to reinsert the prosthesis for an additional six months. Jarvis[13] describes the use of a stainless steel tube after resection of the trachea for a cylindroma. The tube remained clean and patent for eighteen months, but the patient died from massive metastases. Clagett[14] has studied the use of polyethylene tubes as an airway over which the resected ends of trachea or bronchus were anastomosed. This procedure, in general, was unsatisfactory. One of the great difficulties was the loss of the cough reflex (Tables I and II).

Bucher and co-workers,[15] Belsey,[16] Rob and Bateman,[17] and Edgerton[18] have investigated the feasibility of metallic meshes for tracheal reconstruction. Belsey has also studied the use of a wire coil wrapped with host tissue, for tracheal and bronchial replacement.

Accumulated data on these investigations and our own experiences indicate that if it is necessary to use a prosthesis, the metallic meshes have certain distinct advantages.

These materials have enough rigidity to maintain the curvature, arc, and lumen necessary for tracheal reconstruction, but do not have the disadvantages

TABLE I

| AUTHOR | YEAR | PROCEDURE | RESULTS |
|---|---|---|---|
| Gluck and Zeller | 1881 | Incision and anastomosis of trachea (dog) | Good |
| Kuester | 1884 | Excision, stricture of trachea and anastomosis (human being) | Successful |
| Scott | 1928 | Primary suturing of incised trachea (human being) | Good |
| Nach and Rothman | 1943 | Primary suturing of incised trachea (human being) | Good |
| Maisel and Dingwall | 1950 | Excision of short segments with anastomosis (dogs) | Stenosis (1 case) |
| Gebauer | 1950 | Reinforced dermal grafts for bronchostenosis | Conservation of lung |
| Daniel | 1948 | Vitallium, stainless steel mesh, and glass | No long-term successes |
| Longmire | 1948 | Lucite prostheses | No follow-up |
| Jarvis | 1951 | Stainless steel tube | Death from metastases |
| Rob and Bateman | 1949 | Stainless steel and tantalum mesh | Satisfactory result |
| Belsey | 1950 | Wire coil | Satisfactory result |
| Bucher | 1951 | Stainless steel mesh | Satisfactory result |
| Edgerton | 1952 | Wire mesh | Satisfactory result |
| Paulson and Shaw | 1955 | Plastic operations | Conservation of lung |
| Abbott | 1955 | Plastic operations | Conservation of lung |
| Bikfalvi | 1955 | Plastic operations | Conservation of lung |

TABLE II. EXPERIMENTAL DATA

| TYPE OF REPAIR | RESULTS |
|---|---|
| Preserved tracheal homografts | Liquefaction, necrosis, stenosis |
| Diced cartilage molds | Liquefaction, necrosis, disruption |
| Lucite tubes | Angulation, granulation, tissue obstruction |
| Steel wire coils | Temporary support |
| Tantalum and stainless steel mesh | Best results at present |

of a truly rigid tube. The meshes may be covered with skin or fascia, if necessary, and most important, the mesh structure provides a bridge for the lining of the prostheses with the host tissue.

## EXPERIMENTAL DATA

The experiments on tracheal reconstruction were begun at the George Washington University in 1949, and involved the following: tissue grafts, Lucite tubes, hollow bones, steel wire coils, tantalum and stainless steel mesh.*

*Tissue Grafts.*—The first experiment included the removal of segments of the cervical trachea, six rings in length, in 10 dogs, with replacement of the segments with preserved trachea. The tracheal grafts were preserved in modified

*Steel mesh obtainable from United Surgical Supplies Company, Mamaroneck, N. Y.

Tyrode's solution with antibiotics and maintained at minus 4° C. No graft was older than 14 days. The fate of the homograft was determined by sacrificing the dogs at certain intervals (Table III).

TABLE III. TRACHEAL HOMOGRAFTS

| DOG NUMBER | DAYS SURVIVED | CAUSE OF DEATH |
|---|---|---|
| AU-4 | 1 | Tension pneumothorax |
| AV-11 | 8 | Not much wrong (sacrifice) |
| AV-6 | 7 | Pneumonia |
| AW-3 | 34 | Stenosis, pneumonia |
| AW-1 | 25 | Pneumonia |
| AW-013 | 26 | Pneumonia |
| AX-19 | 1 | Distemper |
| AX-22 | 3 | Distemper |
| AY-042 | 1 | Killed because of anoxic paralysis |
| AY-043 | 1 | Never regained consciousness |

The homografts, after one week, seemed to be well healed but, in the period of three weeks, there was beginning liquefaction and necrosis (Fig. 1). In one animal, which lived 34 days, there was a stenosis causing death. Our results were similar to the findings of Ferguson and his co-workers and, accordingly, further studies with homografts were abandoned.

In a second group of 9 animals, the use of cylinders of diced cartilage was studied (Table IV). The method of Peer[19] was employed. Four costal cartilages were diced and placed in a mold of heavy, stainless steel mesh with a glass tube in its center. The ensemble was then implanted into the rectus sheath of a dog. Three months later it was removed and the mesh dissected from the cartilage (Fig. 2). After removal of the glass tube, the hollow cartilage was trimmed to the desired length. These cylinders were composed of a mixture of 50 per cent homologous and 50 per cent autogenous cartilage.

TABLE IV

| DOG NUMBER | AGE OF GRAFT | SURVIVAL TIME |
|---|---|---|
| | *Diced Cartilage* | |
| BB-067 | — | — |
| BC-086 | — | — |
| BC-085 | 126 days | Died, 6 days, empyema |
| BE-0107 | 113 days | Died, 14 days, pneumonia |
| | *50% Homologous—50% Autogenous Cartilage* | |
| BT-311 | Good mold discarded | — |
| BT-300 | Mold liquefied | — |
| BU-331 | Not transplanted | — |
| BU-333 | 150 days | Sacrificed in 120 days for study |
| BU-334 | Incisions opened up in 2 days | |

Later, completely autogenous cartilage was tried. These cartilaginous tubes were placed in the cervical trachea after removal of several rings. The experiment was a total failure; although the diced cartilage maintained its integrity in the rectus sheath, it liquefied when transplanted to the trachea. The combinations of homologous and autogenous diced cartilage not only failed in the rectus sheath, but were totally unsatisfactory after being placed in the trachea (Fig. 3).

*Lucite Tubes.*—Since there has been considerable work with Lucite tubes, only 3 animals were studied with this material. A portion of the cervical

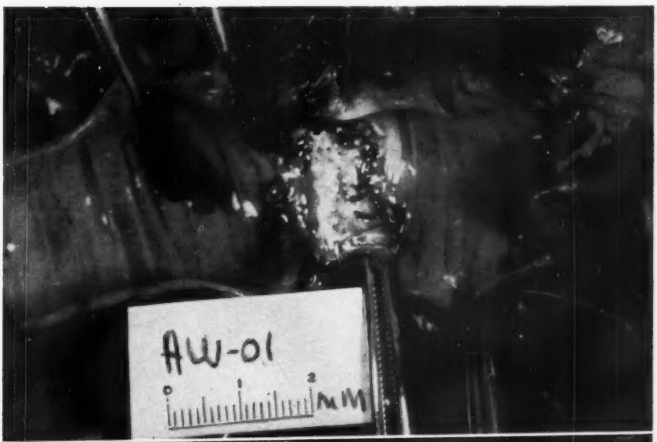



Fig. 1.

Fig. 2.

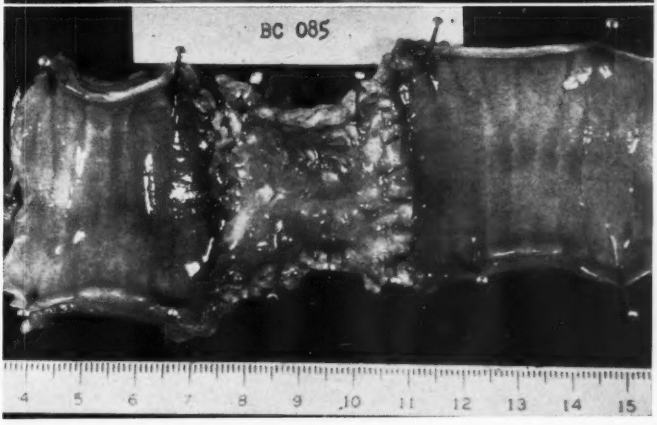



Fig. 3.

**Fig. 1.—Tracheal homograft twenty-five days after insertion. Note beginning liquefaction.**
**Fig. 2.—Molded cartilage. One hundred and twenty-six days.**
**Fig. 3.—Cartilage graft six days after insertion in trachea.**

trachea was excised and a Lucite tube of similar diameter was telescoped into the two ends and held in place by sutures around the trachea and tube. These prostheses were satisfactory in maintaining a noncollapsible airway, but the animals died of pneumonia from 3 to 9 weeks following the operation. At post-mortem examination, the prostheses were found in place, held to the trachea with fibrous tissue. In 2 of the 3 animals, a portion of the trachea had telescoped over the tube and undergone necrosis. There was no gross evidence of respiratory epithelium lining the prostheses, but there was a moderate amount of granulation tissue between the ends of the trachea and the tube. Distal tracheobronchial segments were filled with purulent mucoid secretions. These experiences are similar to Daniel's, who demonstrated that solid tubes of Vitallium, glass, and stainless steel were unsatisfactory because the animals died of pneumonia and suffocation. Stenosis does not occur, or is late, because angulation is prevented with the rigid prostheses (Table V).

TABLE V. TRACHEAL RECONSTRUCTION WITH WIRE SPRING (ENTIRE CIRCUMFERENCE)

| DOG NUMBER | SURVIVAL TIME IN DAYS | CAUSE OF DEATH |
|---|---|---|
| BO-191 | 5 | Pneumonia |
| BO-184 | 88 | Pneumonia |
| BR-257 | 25 | Pneumonia |
| BL-3 | 11 | Empyema, lung abscess |
| BU-330 | 22 | Pneumonia |

*Steel Wire Coils.*—Coils were wound, from No. 28 stainless steel wire, into various diameters. In 5 dogs, five segments of the cervical trachea were removed and the steel wire coil inserted into the defect (Fig. 4). In 2 cases, the coil was placed in the thoracic trachea and covered with a full thickness skin graft. In the remaining 3 animals, the coils were inserted into the cervical trachea without the skin graft covering. Three animals died between the first and third weeks, 2 of pneumonia and one of empyema and lung abscess. The remaining 2 dogs lived one month and 3 months, respectively. Pneumonia and distemper were the cause of death in both animals (Fig. 5).

At autopsy there was no evidence of respiratory obstruction. There was no excessive granulation tissue about the anastomotic line. The springs were found lying free within a fibrous tube. Microscopic sections showed fibrous scar tissue with inflammatory reaction. Only scattered respiratory epithelial cells could be identified.

Experiences of others and our own observations justify the conclusion that the amount of tissue loss will predict the success of the repair. Experi-

TABLE VI. TRACHEAL RECONSTRUCTION
180 DEGREES POSTERIOR
STAINLESS STEEL MESH

| DOG NUMBER | DURATION OF SURVIVAL (DAYS) | FINDINGS |
|---|---|---|
| CM-853 | 90 | Sacrificed; clean mucosa |
| CO-929 | 82 | Sacrificed; clean mucosa |
| CO-936 | 1 | Detachment of graft, put in too tightly |
| CN-903 | 76 | Sacrificed; clean mucosa |
| CO-935 | 27 | Stenosis |
| CP-954 | 63 | Sacrificed; clean mucosa |

ments were then designed to determine the effect of the amount of the circumference of the trachea which had been resected (Table VI).

To study this problem, prostheses were placed in the trachea after 180 degrees of circumference was removed for a distance of five to seven tracheal segments. In one half of the animals, the anterior portion of the organ was excised; in the remaining dogs, the posterior one half was removed. Steel wire coils were employed as prostheses. In animals subjected to resection of the cartilaginous portion of the trachea, the membranous tissue was tacked out laterally to maintain normal tension. The muscles of the neck were sutured around the steel coils. Three of the animals died during the second to the sixth week—one from subcutaneous emphysema, one because the coil was dislodged,

Fig. 4.

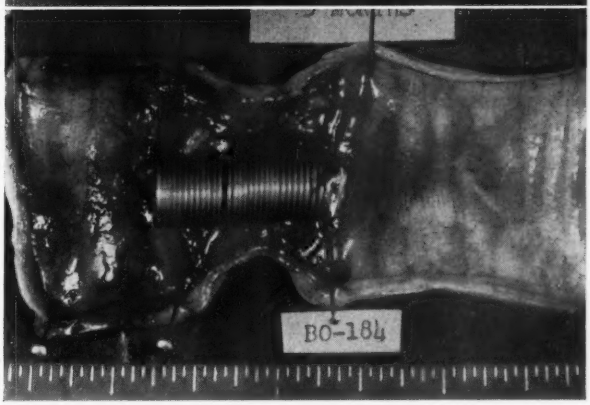



Fig. 5.

Fig. 4.—Roentgen appearance of wire coil in cervical trachea of dog.
Fig. 5.—Appearance of trachea and coil three months after insertion.

and the remainder from pneumonia. In animals that died prior to one month postoperatively, and in animals sacrificed during the same period of time, there was no evidence of respiratory distress. In the dogs which survived 70 to 120 days, or were sacrificed during this time interval, respiratory epithelium could be demonstrated in the cylinder. The points of contact between the steel

spring and trachea, however, were devoid of respiratory epithelium. The findings were identical for the series of animals subjected to the repair of the anterior and posterior halves of the trachea.

It became apparent that the steel coil spring was not a satisfactory prosthesis. Accordingly, further observations were made employing tantalum and stainless steel meshes. Koontz's[20] original study of these two metals in connection with inguinal hernia repair is similar to our impression that tantalum causes more tissue reaction than stainless steel. Moreover, steel meshes provide more rigidity with less tissue reaction.

*Mesh Prostheses.*—Mesh was employed in the following manner: (1) replacement of the anterior, cartilaginous portion of the trachea, (2) replacement of the posterior membranous portion, and (3) replacement of the entire circumference of the trachea. In all instances, six tracheal segments were removed and the mesh placed in the defect.*

*Replacement of the Cartilaginous Portion of the Trachea.*—Five dogs were subjected to the resection of the anterior portion of the trachea. The longest survival was for 14 weeks. The remainder of the animals were sacrificed after one month. In every instance it was possible to demonstrate that normal respiratory epithelium regenerated over the mesh and lay on the fibrous connective tissue which had grown through the interstices of the mesh. In several cases there was sufficient contraction of the fibrous tissue with constriction of the mesh which could have ultimately caused obstruction. Subsequent clinical experiences have made this observation of considerable importance. The respiratory epithelium within the mesh was pink, glistening, and smooth (Table VII).

TABLE VII. TRACHEAL RECONSTRUCTION
180 DEGREES ANTERIOR
COILED STEEL WIRE, TANTALUM MESH, STAINLESS STEEL MESH

| DOG NUMBER | DURATION OF SURVIVAL (DAYS) | FINDINGS |
|---|---|---|
| CG-579 | 19 | Coil dislodged; obstructed |
| CE-553 | 98 | Distemper |
| CH-583 | 91 | Sacrificed |
| CG-571 | 98 | Stenosis |
| CA-494 (Tantalum) | 62 | Infection |
| CG-580 (Tantalum) | 22 | Sacrificed |
| CT-137 (Steel mesh) | 70 | Sacrificed |
| CV-232 (Steel mesh) | 43 | Sacrificed |

The regeneration of respiratory epithelium was equally satisfactory in animals with posterior and anterior resection of the trachea. It is important to emphasize, however, that potential or actual stenosis was much more common when the anterior portion of the trachea was resected. This has an important clinical application (Figs. 6 and 7).

Replacement of the entire circumference of the trachea gave the poorest result. Twelve dogs were used in this experiment; none lived over 52 days. In most cases, death was due to gradual stenosis of the prostheses. It is

*Stainless steel mesh in the original animal experiments was supplied by Davis & Geck, Inc.

interesting, however, that in these animals frequent bronchoscopic examinations revealed clean mucosa with no granulation or ulceration. These findings indicated that the gauge of the mesh to be employed should be determined by the amount of circumferential damage. Small defects are best treated with the finer meshes. Larger ones require heavier, more rigid prostheses. Subsequent experiences with stainless steel mesh, both in the laboratory and in human cases, have verified these observations (Tables VII and VIII).

Fig. 6.—Tantalum mesh prosthesis, anterior. Note bent mesh and incomplete tissue healing. Twenty-two days.

TABLE VIII. TRACHEAL RECONSTRUCTION
360 DEGREES
TANTALUM AND STEEL

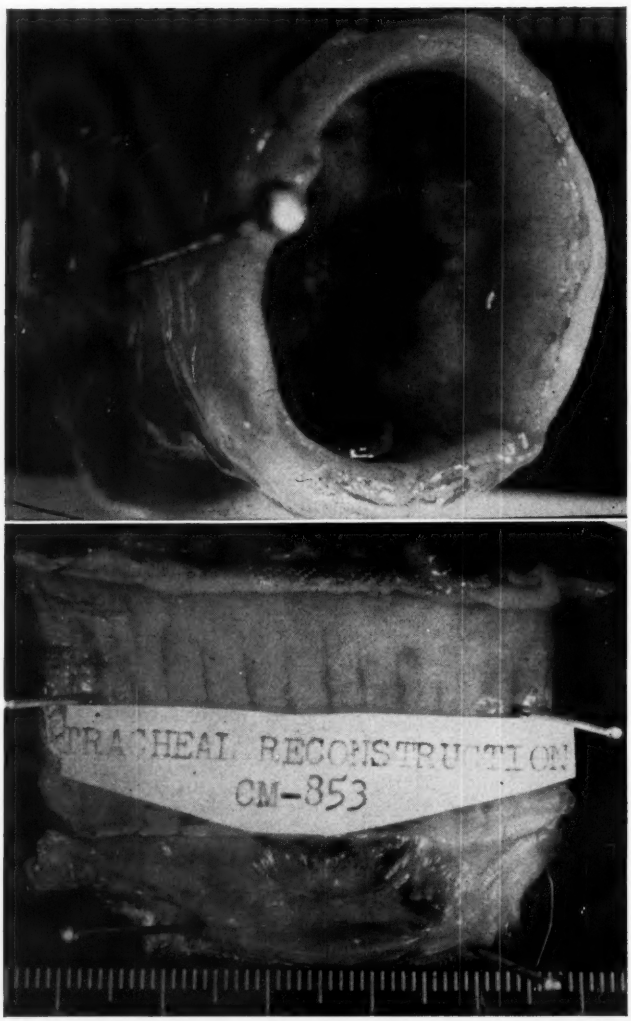
| DOG NUMBER | DURATION OF SURVIVAL (DAYS) | FINDINGS |
|---|---|---|
| CI-600 | 2 | Stenosis due to bending of prosthesis |
| CG-576 | 2 | Nothing wrong |
| CJ-612 | 27 | Stenosis due to bending of prosthesis |
| CJ-617 | 16 | Infection of trachea; wire detached |
| CL-798 | 42 | Stenosis |
| CL-802 | 21 | Stenosis |
| CU-156 (Steel) | 1 | Blood clot, bronchus |
| CQ-1 (Steel) | 52 (died) | No autopsy |
| CV-238 | 8 | Stenosis |
| CV-235 | 12 | No autopsy |
| CV-230 | 1 | Leaked |
| DI-831 | 1 | Leaked |

Correlation of experimental observations and clinical experiences are recorded in the following case reports. It has been established that early primary suture of tracheal defects is the treatment of choice. There are, how-

ever, cases in which prostheses must be employed to restore continuity of the organ. If it is impossible to reconstruct the trachea or a major bronchus without the aid of a prosthesis, it appears that stainless steel mesh is the most desirable available material.

When reconstruction is being considered, one must assess the lesion in this fashion: (1) Site—cervical or thoracic trachea, anterior or posterior wall of

*A.*




*B.*

Fig. 7.—*A*, Stainless steel mesh, posterior wall. Eighty-two days. *B*, Specimen opened.

the trachea. (2) Extent—either the entire or partial circumference of the trachea involved, and (3) whether loss of substance exists. In this manner, the degree of success of the reconstruction may be predicted.

Table IX shows a series of 9 cases, outlining the salient features of each case. Representative cases from this series will be more fully described as follows.

TABLE IX. TRACHEAL REPAIR

| CASE | TYPE OF LESION | SITE | EXTENT OF LESION | TYPE OF REPAIR | RESULT |
|---|---|---|---|---|---|
| 1 | Inflammatory stricture | Thoracic portion | 8 cm. long; 270 degree circumference | Coiled spring steel | Died post-operatively |
| 2 | Self-inflicted | Cervical trachea | 270 degree loss of substance | Stainless steel mesh | Good |
| 3 | Polypoid mass | Thoracic portion | 3 cm.; 270 degree circumference | Stainless steel mesh, No. 48, lined | Died; delayed hemorrhage |
| 4 | Automobile accident | Cervical trachea | Complete section of cervical trachea; both recurrent nerves injured | Stainless steel mesh | Failure |
| 5 | Automobile accident, laceration with stenosis | Thoracic portion | 270 degrees | Incision and transverse repair | Good |
| 6 | Automobile accident, laceration with stenosis | Thoracic portion, lower third | 180 degrees | Incision and transverse repair | Good |
| 7 | Inflammatory stenosis | Right main-stem bronchus, middle lobe orifice | | Resection, middle lobe; incision and repair of bronchus | Excellent |
| 8 | Fracture with stenosis | Cervical trachea | 180 degrees, 4 rings | Stainless steel mesh | Excellent |
| 9 | Recurrent carcinoma | Right bronchial stump | | Excision, stump; stainless steel mesh covered with fascia | Excellent |

## CASE REPORTS

CASE 1.—A 42-year-old Negro woman was admitted to the George Washington University Hospital on Jan. 24, 1951. She was transferred from another hospital because of severe stridor and dyspnea. The obstruction to the trachea was evident. A harsh whistle accompanied each inspiration with audible expiratory wheezes. Bronchoscopy, bronchography, and laminograms established a stenosis of the trachea from below the vocal cords to just above the carina.

The patient was operated upon Jan. 29, 1951 (E. J. B.). A collar incision was made with a vertical extension over the sternum. The sternum was split longitudinally. After the trachea was exposed, it was evident that the cartilaginous rings from the level of the cords to the carina were destroyed. A second incision was made in the right third interspace for better exposure. An endotracheal tube was passed into the left main-stem bronchus

through a short incision above the carina. The stenosed portion of the trachea was resected. This measured 8 cm. in length. The prosthesis of spring steel covered with fascia lata was placed in the defect.

Examination with the bronchoscope immediately after the operation showed a satisfactory lumen. The patient tolerated the operation well, and repeated endotracheal aspirations were performed to keep the airway clear. The patient died two days later. The lumen of the prosthesis was adequate; however, the entire trachea and major bronchi were filled with thick, tenacious secretions. Both lower lobe bronchi showed severe bronchiectasis.

A proximal tracheostomy should have been performed, not only for control of secretions but for reduction of dead air space. This was not possible because the prosthesis started just below the larynx.

*A.* *B.*

Fig. 8.—*A*, Case 1, showing coil and fascia lata covering at autopsy. *B*, Case 1. Specimen opened showing thick tenacious secretions.

CASE 3.—A 45-year-old Negro man was admitted to the District of Columbia General Hospital on Oct. 20, 1952, for the third time. All admissions had been the result of chronic respiratory tract infection. In the course of the hospital work-up, a bronchoscopic examination revealed a polypoid lesion in the mid-trachea, which was biopsied and reported to be squamous metaplasia. The patient was treated with antibiotics and bronchodilators. There was no improvement on medical therapy. Persistence of this polypoid lesion, which was increasing in size, was considered an indication for surgical intervention.

On Dec. 2, 1952, the patient was operated upon. A collar incision was made with a vertical component down over the sternum. The trachea was exposed in the neck and by splitting the sternum, additional exposure was gained below. The trachea was mobilized and elevated by using two large tissue drain slings. A small incision was made into the left lateral wall of the trachea. The tumor was seen at the point of incision in the trachea. A segment of trachea, 2 by 3 cm. in size, involving the posterior wall and the left anterolateral wall was excised. The defect was covered with a piece of No. 40 stainless steel mesh. A split-thickness graft was used for the lining of this mesh and the entire ensemble was stitched into place. The new segment was airtight. After the chest had been closed, a proximal tracheostomy was performed in the cervical trachea.

The postoperative course was fairly smooth and the patient was soon up and about the ward (Fig. 9). The tracheostomy tube was removed on the fifteenth postoperative day. The patient complained occasionally of a scratchy sensation in his throat and on occasion coughed up some frothy, blood-streaked sputum. On the morning of the twentieth postoperative day, the patient had a fatal hemoptysis.

Autopsy revealed that although the mesh was intact and in place, a small, roughened portion had eroded the wall of the innominate artery.

In subsequent work, a different size mesh has been used and careful attention given to the preparation of the hem to ensure against any rough or protruding edges.

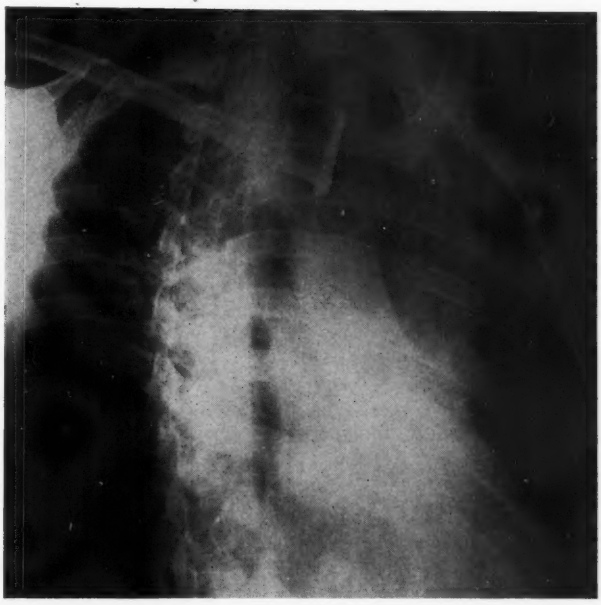


Fig. 9.—Case 3. Mesh in place.

CASE 5.—A 31-year-old Army corporal was injured in an automobile accident on Oct. 20, 1952. Among other injuries, he sustained a fractured sternum, with a laceration of the trachea just above the carina. He was admitted to a Station Hospital and a right hemopneumothorax with subcutaneous emphysema was shown on a roentgenogram. The patient's symptoms subsided rapidly and the lung gradually re-expanded. However, on Nov. 2, 1952, the patient again complained of respiratory difficulty. A bronchoscopy performed at that time revealed a laceration of the trachea, involving two thirds of the circumference, from 11 to 7 o'clock, just above the carina. A small flap of mucosa could be seen, which had a to-and-fro motion on respiration. Tracheostomy was performed which alleviated the respiratory distress. On Nov. 7, 1952, during another bout of respiratory distress, cyanosis and convulsions occurred. The tracheostomy tube was removed and a bronchoscopy was performed through the tracheostomy. The bronchoscopy revealed an area of stenosis at the site of injury, about 2 inches above the carina. Granulation tissue could be seen at this site. It was necessary to improvise a long tracheostomy tube, which was then passed down beyond the site of injury.

The patient was transferred to the Walter Reed Army Hospital, where bronchograms revealed a constriction of the trachea at the previously described site. Since no progress

in the patient's condition was evident, it was decided to attempt a plastic procedure on the trachea for correction of the stenosis.

On July 9, 1953, through a right thoracotomy, the carina was mobilized. An elliptical piece of trachea, involving the stenotic portion was resected. The defect was then repaired transversely over the indwelling endotracheal tube. The postoperative course was smooth. However, in August, 1953, the patient developed nausea, fever, and loss of weight. In addition, respiratory distress again developed. It was necessary to reinsert the long tracheostomy tube, down past the site of the previous operation. Bronchoscopy revealed that the previous site of repair had again stenosed so that the lumen was markedly decreased (Fig. 10). Through the bronchoscope, with a biopsy forceps, small pieces of the strictured portion were removed, until an adequate lumen was obtained. A tracheostomy tube was reinserted and left in place for a few days. After the tube was removed, the respirations were smooth and the patient was gradually able to resume ward duties without difficulty.

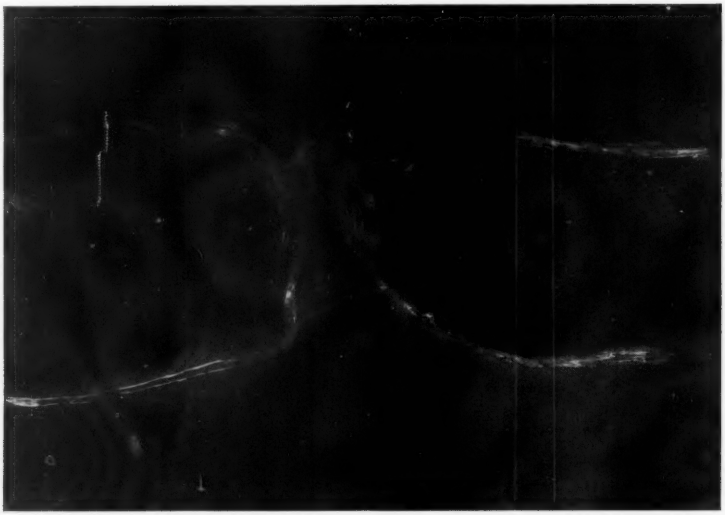


Fig. 10.—Case 5. Lateral view of stenotic trachea. (Retouched by author.)

A bronchogram at the time of discharge from the hospital revealed an adequate lumen. This illustrates how a small difference in the internal circumference of the trachea permits comfortable breathing.

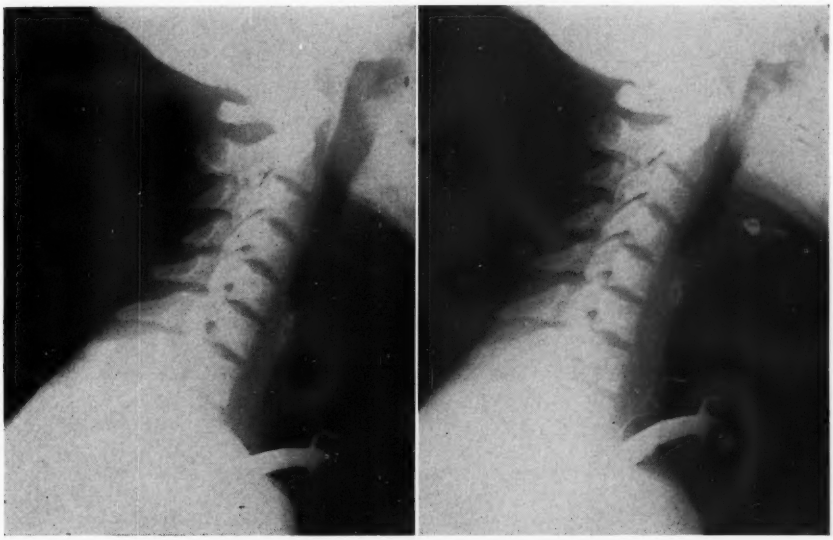
CASE 8.—A 19-year-old Negro male college student was admitted to the George Washington University Hospital for elective repair of a traumatic stenosis of the trachea.

In August, 1955, the patient was involved in an automobile accident, sustaining lacerations of the neck and trachea. An emergency tracheostomy was performed at a nearby hospital. When the patient had recovered from his immediate shock, three separate elective attempts were made to repair the tracheal stenosis. However, in each instance it was necessary to abandon the procedure and reinsert the tracheostomy tube.

Bronchoscopy performed at the George Washington University Hospital was technically difficult because the larynx was distorted from its usual position. Approximately 5 cm. below the vocal cords, the tracheal lumen suddenly narrowed to about 3 mm. in diameter. It was possible to pass a right-angle telescope through the stenosis and the distal trachea was normal in appearance. A tracheogram confirmed this (Fig. 11*A* and *B*).

On Sept. 28, 1955, operation was performed. A flexible endotracheal tube was passed down through the tracheostomy for administration of anesthesia. A long, vertical incision

was made from the prominence of the cricoid cartilage to the suprasternal notch. The tissues in the area were difficult to dissect because of dense scar. After the trachea had been exposed, four damaged tracheal rings could be seen. They were crushed and deformed. The anterior half of the trachea, involving the deformed cartilage, was resected and the stenotic area removed. An endotracheal tube was then inserted from above. A previously prepared piece of No. 40, stainless steel mesh was fashioned and rolled to fit the arc and contour of the trachea (Fig. 11*C*). It was fitted into place over the defect and sutured,



*A.* *B.*

Fig. 11, *A* and *B*.—Case 8. Lateral views with and without Lipiodol outlining defect.

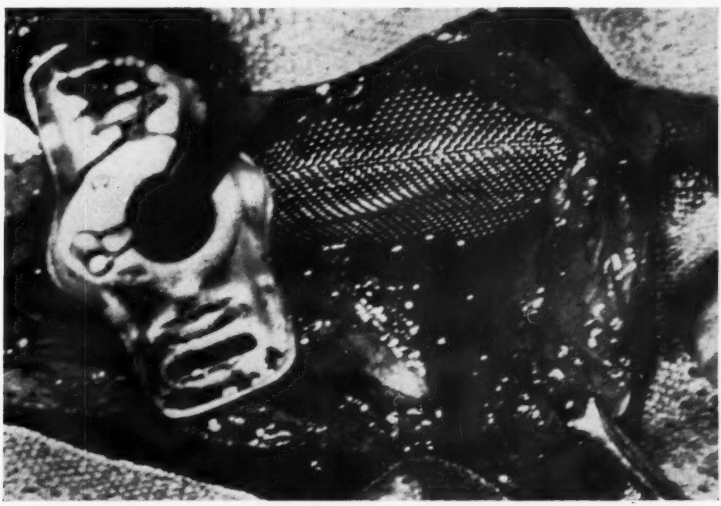


Fig. 11*C*.—Operation completed and mesh in place.

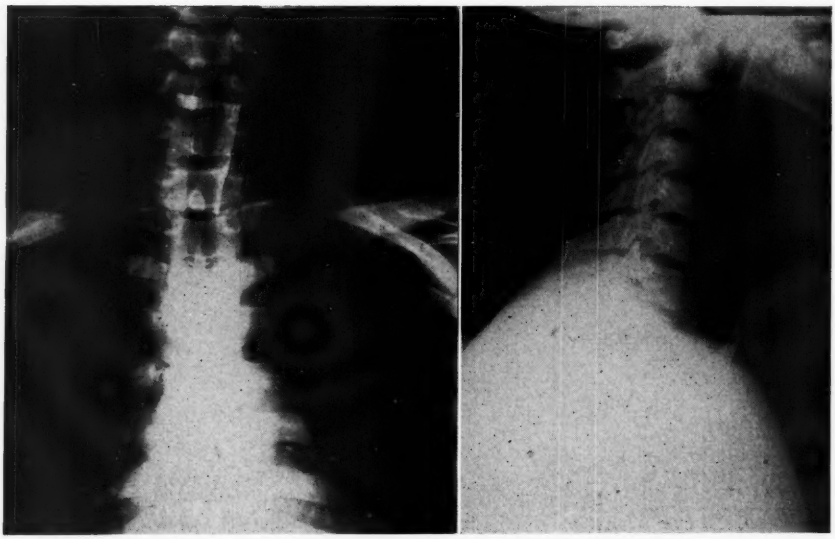


Fig. 11*D*.—Front and lateral views showing absence of stenotic zone and mesh in satisfactory position.

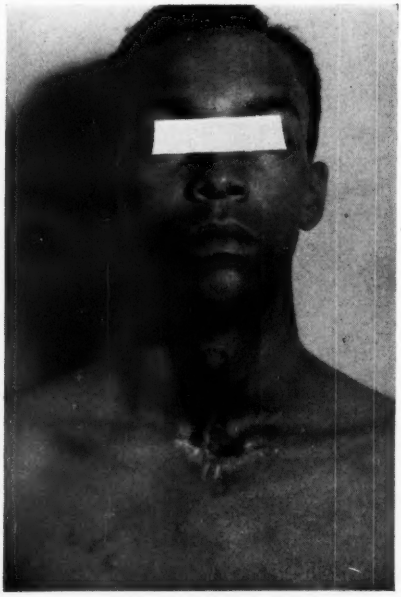


Fig. 11*E*.—Case 8.

using No. 32 stainless steel wire. A proximal tracheostomy was performed through the cricothyroid membrane. The immediate postoperative course was satisfactory. However, the scar developed keloid transformation. At about the same time, insidious respiratory distress and stridor developed. It was necessary to reinsert the tracheostomy tube, and subsequent bronchoscopies revealed that the site of repair had become stenotic. Accordingly, a second operation was performed. The keloid scar was resected and the previously inserted mesh, which had now become twisted and bent, was also removed. The edges of

Fig. 12.—Case 9. Laminogram showing lumen after reconstruction of trachea at right main bronchial orifice.

the tracheal defect were freshened. A sheath of No. 46 stainless steel mesh was prepared, similar to the original prosthesis. It was placed over the defect and again sutured into place using No. 32 stainless steel wire (Fig. 11*D* and *E*).

The postoperative course was satisfactory and the tracheostomy tube was removed in seven days. Because of the previous keloid formation, x-ray irradiation was begun. The patient's hospital course was entirely satisfactory and he was discharged to return to college. He returned for a follow-up examination in April, 1956, and there was no evidence of respiratory distress. Moreover, no recurrence of the keloid formation could be seen.

A successful repair, using the same technique with a stainless steel mesh prosthesis, was performed more than five years ago. The patient has no respiratory difficulty. In this particular case, the second operation was necessary because of compression of the mesh prosthesis by excessive keloid formation.

A combination of heavier mesh and x-ray irradiation to reduce keloid formation was followed by a satisfactory result.

## SUMMARY

Experiments were carried out, in dogs, to study the problem of tracheal reconstruction. Tissue grafts, steel wire coil, and tantalum and stainless steel mesh were used. The results were not satisfactory when rigid prostheses were used and when the entire circumference of the trachea was replaced. However, if only the anterior wall or the posterior wall of the trachea was replaced, the incidence of stenosis was decreased. Stainless steel mesh, because of its tissue acceptability, its flexibility and incorporation by the body tissues appears to be a satisfactory prosthetic material.

Nine cases of tracheal reconstruction are presented, in which stainless steel mesh was used as a prosthesis in 5. A steel coil spring prosthesis was used in one, and plastic procedures to restore continuity sufficed in 3. In one case, the use of a stainless steel prosthesis was a failure, in another death occurred after erosion of a great vessel.

Experimental and clinical evidence indicate the superiority of stainless steel mesh for a tracheal prosthesis.

## CONCLUSIONS

Whenever possible, suturing of tracheal defects should be performed.

The lesion should be assessed carefully.

If a prosthesis is required, stainless steel mesh is recommended.

Simple plastic procedures are satisfactory for short, stenotic segments.

Proximal tracheotomy is mandatory when a prosthesis is used.

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## DISCUSSION

DR. DAVID H. WATERMAN, Knoxville, Tenn.—I rise to report a case of extensive tracheal damage in which the repair failed. The patient was a 20-year-old girl in whom an automobile accident injury, tracheotomy, and subsequent infection resulted in a 360 degree destruction of the trachea for a distance of 7 cm. above the carina. Several months after the accident, when she was sent to us, a repair was effected by excising essentially the entire stenotic lower trachea and inserting a skin-covered and lined stainless steel mesh tube. The patient did well for ten days, and then died from a torrential hemorrhage from erosion of the innominate artery, which had apparently been considerably weakened when it was dissected out of the mass of scar tissue.

Certainly the problem of extensive stenosis, such as this case illustrates, is a very serious one. I should like to congratulate the authors both on their presentation and their results.

DR. OSLER ABBOTT, Emory University, Ga.—I too wish to compliment the excellence of this presentation. There are four small points I wish to dwell upon.

First, in a recent attempt by us to remove the entire inner lining of the trachea throughout its length for diffuse papillomatosis, we were impressed with the value of a full-length sternal splitting incision. Temporary transection of the innominate vein and by-pass graft for the innominate artery would then allow excellent access to the lower trachea and carina. Second, I wish to present to this Association a follow-up of the work presented here two years ago relative to extending the indications for bronchial grafts. In the first place, the dermal grafts used in the trachea and bronchi of two children have continued to grow with the children for a period now of five and seven years, respectively. In the second place, we reported the use of grafts in patients with carcinoma of the lung. There have been 4 patients treated by lobectomy with dermal grafting, and one radical right pneumonectomy with excision of considerable trachea, the carina, and some of the left main-stem bronchus. All 6 of these patients are still surviving without evidence of recurrence for periods now of 18, 25, 30, 34, and 38 months. No delayed stricture or other complication has occurred in this small patient group.

Finally, we have been interested in the Papanicolaou studies on the sputum and bronchial secretions of patients with dermal bronchial grafts. In one instance, suspicious cells listed as Class III and Class IV have appeared repeatedly for eight months following lobectomy and grafting for a carcinoma in situ.

In summary, then, our long-term follow-up studies of patients treated with Gebauer-type dermal grafts confirm our initial optimism regarding this procedure.

DR. ALLEN STRANAHAN, Albany, N. Y.—I would like to present one case.

(slide) This case illustrates what the authors have described. We used a stainless steel mesh dermograft to replace the tracheal defect, but in addition we feel it is important

to emphasize the fact that in reinforcing the graft a pleuroperiosteal flap should be used around the stainless steel mesh. This 38-year-old patient presented herself with the usual symptoms of cough and wheeze. At operation the trachea was isolated, a longitudinal opening was made in the membranous portion of the trachea to identify the extent of the tumor in this area of the trachea.

(slide) The tumor-bearing tracheal mucosal ring was dissected in this manner. Here you see the endotracheal tube.

(slide) The stainless steel mesh dermograft was applied using interrupted fine silk sutures. To help prevent the hazards of this stainless steel mesh from eroding the surrounding vessels, a pedicle flap of periosteum from the chest wall and pleura and surrounding mediastinal tissue was used to encircle the graft. To date, some three or four months following operation, the patient is doing quite well.

DR. K. ALVIN MERENDINO, Seattle, Wash.—We too have had some experience with these methods in human beings. I would like to speak particularly on the experimental approach. A few years ago, Dr. Kiriluk and I were interested in tantalum mesh as a substitute for excised segments of the trachea. This, in our hands, proved unsatisfactory for total circumferential replacement. The problem of replacement in both trachea and esophagus is that of finding a material that is sufficiently firm so that it is not compressible, and yet not so hard that it will erode adjacent tissue.

Recently my associate, Dr. John E. Jesseph, has been working with Ivalon sponge molded to shape, into which he has incorporated fine Lucite rings to simulate tracheal rings. This prosthesis is held in place by a nonsuture method, similar to the multiple-point fixation method that Dr. Hufnagel used for his prosthetic aortic valve. In our opinion, at the present time, this is the best material we have yet utilized in tracheal replacement.

DR. O. T. CLAGETT, Rochester, Minn.—I have enjoyed this paper on tracheal reconstruction very much. One application of tracheal resection and reconstruction that should be discussed further concerns its use in the treatment of tracheal tumors. In a recent study one of my colleagues, Dr. F. H. Ellis, Jr., reported a series of 82 cases of tracheal tumors seen at the Mayo Clinic. These are not common lesions, but they do merit our interest. Some years ago, Dr. J. Grindlay and I carried out some rather extensive studies in the experimental laboratory trying to develop techniques for the resection of tracheal lesions. Using the techniques we had worked out in the laboratory, I have up to the present time operated upon 4 patients with tracheal tumors. In the first, a cylindroma of the lower trachea and right bronchus was removed, and the left main bronchus was connected to the trachea by a polythene tube. This patient died of pneumonia of the left lung approximately one week after operation. In a second case, a polythene tube was used to replace a segment of trachea removed for a primary squamous-cell carcinoma of the trachea. This patient died of metastases two years later. In 2 patients, cylindromas of the trachea were removed by local excision and repair of the tracheal defect was made by a wire reinforced fascial graft. One patient died of recurrent tumor over two years later, the other patient was still alive and well when last heard from about four years after operation.

There is a definite need for methods of resection and reconstruction of the trachea for a variety of lesions. Dr. Keshishian, Dr. Blades, and their associates are to be congratulated on the results they have had. I believe that some type of plastic prosthesis, such as Dr. Merendino has described, will provide an excellent means for tracheal reconstruction. Anesthesia and adequate oxygenation of the patient during operation have offered difficulties, in our experience. I am hopeful that with some of the extracorporeal circulation machines that are now being used successfully for cardiac surgery, it will be possible to obviate these problems and that it will be possible to resect and reconstruct the trachea without having to worry about airway and oxygenation problems during the procedure.

DR. BEATTIE (Closing).—We would like to thank the discussants for their contributions to this particular problem, and we want to point out that there are as yet many unsolved problems. Certainly replacement of the entire trachea, although it is technically pos-

sible, has not as yet been solved. The first case we presented demonstrated one of these points, inasmuch as the trachea was replaced from one centimeter above the carina to approximately one centimeter below the larynx. The difficulty was primarily with secretions, not with the technique of getting the graft in or air leaks, and we should have used a laryngeal fissure operation. We are convinced that the control of secretions with tracheotomy is necessary.

Dr. Waterman pointed out that one of his cases also hemorrhaged from blood vessels in the thorax. In the case of ours that had the hemorrhage, a median sternotomy incision was used and the innominate artery was displaced while the dissection was being done. It was not until the retractor was released and the incision came back to normal that it was realized that the artery was going to press on the prosthesis. So perhaps some attention should be paid to this point if the median sternotomy incision is used. Certainly when homologous grafts are accepted as well as autologous grafts, we will then have the ideal replacement for the trachea. With that idea in mind, I would like to mention that Dr. Correll in our laboratory at Presbyterian Hospital in Chicago has been studying some of these points, and you might be interested to know that in the use of the autologous grafts he has found that it takes about three weeks even with an autologous graft, to get the trachea back to normal with the cilia regenerated. He has also found something else of interest. If he turns the trachea around after the cilia have regenerated, the cilia beat is caudad rather than cephalad. There is an inherent polarity to ciliary action, and it is suggested that if an autologous tracheal graft is used, note should be made of which way the cilia were beating and insert them in the same direction.

(slide) This is an interesting patient who has already been mentioned; a man in his 60's who came in with a carcinoma of the lung in the right upper lobe, an epidermoid carcinoma. He had a right pneumonectomy and returned eighteen months later with a recurrence of carcinoma or a new carcinoma in the bronchial stump. Much to our surprise it was possible to resect the tumor. We came across no tumor outside the airway. We resected the carina, part of the medial wall of the left main bronchus, the right bronchial stump, part of the right lateral wall of the trachea, over a distance of 5 cm. in length and about 2.5 cm. in diameter. We replaced this with stainless steel mesh and fascia lata. This is a laminogram taken two and one-half years after operation. The patient is alive and well after three years. I persuaded him to let me bronchoscope him a short time ago and, to my surprise, since he had no symptoms, there are still a couple of areas where the mesh is not covered or lined by ciliated epithelium. You can see bare wire and a few strands of wire waving. But he has had no complaints and we thought we would let well enough alone.

I think we can say that a 180-degree circumference of the tracheal resection can be handled reasonably well with wire mesh. It is still a baffling problem and I agree that plastic techniques are probably the best. I think the optimum repair will result through the use of homologous transplants when they have been desensitized.

# THE SOLITARY PULMONARY NODULE

## A Ten-Year Study Based on 215 Cases

Edgar W. Davis, M.D., J. Winthrop Peabody, Jr., M.D., and Sol Katz, M.D.
Washington, D. C.

IN 1946, one of us (E. W. D.), impressed by the general unconcern about the small solitary pulmonary nodule and particularly distressed by the late stages in which so many of these patients were being referred for operation, initiated a study of our own experience with these lesions. In the original group of 40 patients reported in 1947,[1] the malignant proportion was inordinately high and the need for earlier resection was clearly shown. Ten years later, although still short of ideal, the situation is a happier one with patients operated upon sooner, often in the asymptomatic phase, thanks to a wider appreciation of the hazards inherent in the unresected nodule. The radiologist has come to regard it as a diagnostic impasse. An increasing number of practicing physicians, still too few unfortunately, have become aware of the grave responsibility they assume in handling this lesion and are now reluctant to propose a program of observation. Thoracic surgeons are uniformly agreed on the advisability of prompt diagnostic thoracotomy. Even so, we continue to see a regrettably large number of neglected nodules and the problem instead of being resolved has reached tremendous proportions due to the more liberal use of routine and survey chest roentgenograms. It is certainly the most common single indeterminate pulmonary lesion that we see in surgical consultation and at least one radiologist has referred to it as the most urgent problem facing the radiologist today.[2]

*Purpose.*—To date the main theme of all papers on this subject pertains to the malignant propensities of the group as a whole and the lack of significant radiographic distinctions other than calcification to differentiate the benign from the malignant nodule. One purpose of this paper is to re-emphasize this fairly trite aspect of the problem, but equally important questions remain unanswered, and it is with these issues that this survey is primarily concerned. Chief among these are (1) survival rates of patients with resected bronchogenic carcinoma which presented as a solitary pulmonary nodule; the influence of time factors, symptoms, and mediastinal node involvement upon survivorship; (2) reliability of calcification within the nodule as an indication of benignity; and (3) reappraisal of the etiology of the so-called tuberculoma.

*Definition.*—Cases have been selected on essentially the same radiographic criteria laid down in 1947[1] and utilized in our subsequent reports in 1950[3] and

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1955.[4] To these we now feel obligated to add a size restriction so that our material can be correlated with that of other authors.

1. The nodule must be 6 cm. or less in diameter. Larger nodules have been included only if previous roentgenograms show the lesion to have been smaller than 6 cm. when originally detected.

2. The nodule must be solitary, although small satellite lesions may be present.

3. The nodule must appear to lie within pulmonary parenchyma with aerated lung around it. A relatively minor pleural component has not been considered grounds for exclusion; neither has its proximity to the hilus, provided the lateral roentgenogram shows the nodule to lie anterior or posterior to the hilus. Obvious hilar, mediastinal, diaphragmatic, and chest wall masses have been excluded.

4. Its shape is round or ovoid. Lobulations if present must be minimal.

5. Its margins are circumscribed and its contour is smooth. Extreme sharpness of outline has not been required.

6. There is no demonstrable calcium nor cavitation within the nodule.

7. There is minimal if any associated pneumonitis, atelectasis, or regional lymphadenopathy. Although the majority of these patients have been asymptomatic, an absence of symptoms has not been required for classification under the heading of solitary intrapulmonary nodule.

*Terminology.*—There has been considerable diversity of opinion as to what to call these lesions. We originally suggested the term solitary intrapulmonary tumors and many variations of the same idea have been proposed; solitary lung tumors,[5] isolated pulmonary nodules,[6] single, circumscribed, intrathoracic densities,[7] circumscribed discrete pulmonary lesions,[8] circumscribed solitary lung lesions,[9] asymptomatic isolated intrathoracic nodules,[10] solitary circumscribed lesions of the lung,[11] solitary circumscribed intra-thoracic radio-opacities,[12] solitary pulmonary lesion,[13] spherical lesions of the lung,[14] asymptomatic isolated pulmonary nodule,[15] solitary discrete pulmonary densities,[16] circumscribed peripheral shadows of the lung,[17] nodular densities in the lung,[18] etc.

The complete lack of uniformity is confusing and undoubtedly is partly responsible for the way in which the term "coin" lesion[19] has gained such popularity.[20-33] To our mind this is a poor compromise and we have so expressed ourselves previously.[34] As Rigler points out it "is commonly miscalled a 'coin' shadow but actually represents a spherical nodule."[35] Holt and Hodges even go so far as to refer to it as "that odious term 'coin lesion.' "[36] Agreeing in point if not in degree, we prefer to call these lesions solitary pulmonary nodules.

*Historical Highlights.*—Graham and Singer[37] are generally credited with the first series of resected solitary pulmonary nodules. Their report, published in 1936, concerned three partially calcified benign lesions that were suspected preoperatively of being tumors. No specific etiology was established for any of the three, two being obvious granulomas by present-day standards and the other in all probability a bronchogenic cyst.

TABLE I

ANALYSIS OF REPORTED SERIES

| LESION | O'BRIEN, TUTTLE & FERKANEY 1948 | EFFLER, BLADES & MARKS 1948 | MAHON & FORSEE 1950 | SHARP & KINSELLA 1950 | HUSFELDT & CARLSEN 1950 | ABELES & EHRLICH 1951 | EFFLER 1951 | HARE & BATTERSBY 1952 | BELL & SEALY 1952 | WOLPAW 1952 | CONDON 1952 | STOREY, GRANT & ROTHMANN 1953 | HOOD, GOOD, CLAGETT, & McDONALD 1953 | DEANS 1953 | MAY, ROSE & DUGAN 1954 | JONES & CLEVE 1954 | MECKSTROTH, ANDREWS & KLASSEN 1954 | WU SHAO-CHING et al 1954 | WILKINS 1955 | HIGGINSON & HINSHAW 1955 | AXTMAYER & EHRLICH 1955 | COHEN & BORTONE 1955 | FORD, KENT, NEVILLE & FISHER 1956 | FRENCH et al 1956 | DAVIS, PEABODY & KATZ 1956 | TOTALS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRONCHOGENIC CARCINOMA | 8 | 1 | 2 | 11 | 8 | 5 | 6 | 1 | 8 | 6 | 17 | 4 | 25 | 15 | 8 | 1 | 11 | 1 | 27 | 5 | 2 | 2 | 59 | 4 | 79 | 316 | |
| BRONCHIAL ADENOMA | | | 1 | 2 | 1 | 1 | | 1 | 3 | 2 | | | 12 | 2 | | | | | 2 | 1 | | | 5 | | 9 | 42 | 358 (29.7%) |
| PRIMARY SARCOMA | 1 | 1 | 1 | | | 1 | | | | | 1 | | 1 | | | | 2 | | | | | | | | 2 | 10 | |
| LYMPHOMA | | 1 | | 1 | | | | | | | | | | | | | 2 | | | | | | | | 1 | 5 | |
| METASTATIC TUMOR | | 1 | 1 | 3 | 2 | 1 | 1 | 1 | 1 | 2 | | 3 | 17 | 1 | 4 | | 12 | | 6 | 1 | 1 | | 1 | | 10 | 69 | |
| TOTAL MALIGNANT | 9 | 4 | 5 | 17 | 11 | 8 | 7 | 3 | 12 | 10 | 18 | 7 | 55 | 18 | 12 | 1 | 27 | 1 | 35 | 7 | 3 | 2 | 65 | 4 | 101 | 442 (36.7%) | |
| GRANULOMA | 8 | 7 | 48 | 21 | 2 | 5 | 8 | 2 | 10 | 10 | 2 | 30 | 65 | 16 | 18 | 10 | 29 | 8 | 20 | 19 | 6 | 4 | 50 | 22 | 82 | 502 (41.6%) | |
| HAMARTOMA | 1 | 1 | 2 | 6 | 5 | 1 | 1 | | | 2 | 4 | 2 | 25 | 4 | 3 | 2 | 7 | | 11 | 9 | | 1 | 1 | 3 | 9 | 100 | |
| BRONCHOGENIC CYST | 1 | 6 | | 8 | 4 | | | | 1 | | 1 | | 4 | 9 | | 1 | 3 | | 4 | 2 | | 1 | 1 | | 6 | 52 | |
| CHRONIC PNEUMONITIS | | | | | | | | 1 | | | | | 1 | 4 | | | | | | | | 1 | 3 | 7 | 4 | 21 | |
| ECHINOCOCCUS CYST | | 1 | | 1 | | | | | | | | | | 15 | | | | | | | | 1 | | | | 18 | |
| MESOTHELIOMA | | | | | | | | | | | | | 3 | | | | | | 3 | | | | | | 6 | 12 | |
| NEUROFIBROMA | | 1 | | | | 1 | | | | | | | | 5 | | | | | 1 | 1 | | | | | 2 | 11 | |
| CHRONIC ABSCESS | 2 | | | | 1 | 2 | | | | | | | 1 | | | | | | | | | | | | 2 | 8 | |
| FIBROMA | | | | 2 | | | | | | 1 | | | | | | | 3 | | | | | | | | | 6 | |
| LIPOID GRANULOMA | | | | | | 1 | | | | | | | | | | | | | 1 | | | | 1 | | 1 | 4 | |
| HEMANGIOMA | | 1 | | | 1 | | | | | | | | 1 | | | | 1 | | | | | | | | | 4 | |
| A-V ANEURYSM | | | | | | | | | | 1 | | | | | 1 | | | | | | | | 1 | | | 3 | |
| THYMOMA | | | | | | 1 | | | | | 1 | | 1 | | | | | | | | | | | | | 3 | |
| LYMPH NODE | | 1 | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | 3 | |
| LIPOMA | | | | | | | | | | | | | | 1 | | | | | | 1 | | | | | | 2 | |
| BRONCHIECTATIC CYST | | | | | | 1 | | | | | | | | | | | | | | | | 1 | | | | 2 | |
| XANTHOMA-MYXOMA | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | 2 | |
| MISCELLANEOUS | | | | | | | | | | | 1 | | | 3 | 2 | | | | 1 | | | | | | 1 | 8 | |
| TOTAL BENIGN | 12 | 18 | 50 | 38 | 13 | 12 | 9 | 3 | 11 | 14 | 9 | 33 | 101 | 58 | 24 | 13 | 43 | 8 | 42 | 32 | 6 | 9 | 57 | 32 | 114 | 761 (63.3%) | |
| TOTAL CASES | 21 | 22 | 55 | 55 | 24 | 20 | 16 | 6 | 23 | 24 | 27 | 40 | 156 | 76 | 36 | 14 | 70 | 9 | 77 | 39 | 9 | 11 | 122 | 36 | 215 | 1203 | |

In 1942, Alexander[38] emphasized the threat of malignancy in solitary nodular lesions but he obviously had reference to much larger lesions than those we are now considering. The same is true of the report by Thornton, Adams, and Bloch,[39] whose paper, like others appearing later,[40-42] set no restriction as to size or peripheral location of the tumor, hence should not be confused with the very precise lesion we are dealing with in this study.

The evolution of our own interest in this problem has been mentioned in the introduction of this paper. The first published reports of a similar study were those by Effler, Blades, and Marks[5] and by O'Brien, Tuttle, and Ferkaney,[19] both in 1948. Many additional reports have since appeared. Those in which the specific pathologic diagnoses were tabulated plus our own are presented in Table I.[5-15, 19, 23, 28, 29, 32, 33, 43-49] Several papers are not included in this tabulation because of an inadequate breakdown as to the kinds of nodules[21, 50, 51] or because radiologic diagnoses were included.[52]

*Analysis of Combined Series.*—As Table I indicates, each series has included a significant number of malignant lesions, the military hospitals seeming to have a somewhat lower incidence,[5, 23, 33, 43] due no doubt to the younger age group encountered. Surveying the entire combined series one finds that the malignant lesions make up 36.7 per cent of the total. Taking the bronchogenic carcinomas and bronchial adenomas together, which is amply justified by the malignant potentialities of the adenomas, the percentage of actual and potential primary carcinomas of the lung is almost exactly 30 per cent. Metastatic tumors number 69, over one-half being concentrated in our series and two others.[11, 48] It would appear therefore that the chance of any solitary pulmonary nodule being malignant is almost 40 per cent; the chance of it being a bronchogenic carcinoma, around 30 per cent.

As one would anticipate the largest single pathologic entity in the combined series is the granuloma which comprises 41.6 per cent of all cases. Because of the difficulty in determining which of the tuberculomas were tuberculomas in fact and not just in name, meaning positive identification of the organism, all granulomas have been classified under this broad nonspecific term. Of the assorted benign tumors by far the most common is the hamartoma totalling 100 in all (8.3 per cent) and, in one series,[11] amounting to 16 per cent of the total. A wide variety of other nodules have been reported and will be discussed in detail later. One point requiring explanation is the extraordinarily high number of echinococcal cysts included in the total group. This figure is quite out of proportion to the relative rarity of echinococcosis in this country and merely reflects the inclusion of Deans' report[12] from Australia where the disease is endemic. The total number of cases in these combined series is 1,203, a figure large enough to correct for whatever slight differences may exist between different series in their selection of cases. Thus, the higher rate of malignancy introduced in some series by the inclusion of somewhat larger tumors should be easily offset by the inclusion of calcified and cavitary lesions in other groups.

*Analysis of Our Own Series.*—Our own experience is based on 215 cases each of which has been carefully selected according to the strict radiologic criteria outlined earlier. These are tabulated in Table II. The material covers a period from 1942 through 1955, with a larger number of cases occurring in each successive year. These figures do not represent the total number of cases seen, for we have always regarded the partially calcified nodule as relatively innocuous and have been content to observe a good number of them. We are firmly convinced that the exclusion of calcified and cavitary lesions from this series is what accounts for the somewhat higher percentage of malignancy in our group. As the Mayo Clinic group has shown, the percentage of malignancy in their series rose from 35 per cent to 42 per cent simply by dropping those nodules with radiographically demonstrable calcification.

TABLE II. 215 SOLITARY PULMONARY NODULES

| LESION | | CASES | |
|---|---|---|---|
| Bronchogenic carcinoma | | 79 (36.7%) | |
| Squamous carcinoma | 34 | | |
| Adenocarcinoma | 27 | | |
| Bronchiolar carcinoma | 9 | | |
| Undifferentiated carcinoma | 9 | | |
| Bronchial adenoma | | 9 | |
| Fibrosarcoma | | 1 | |
| Leiomyosarcoma | | 1 | |
| Lymphoblastoma | | 1 | |
| Metastatic tumor | | 10 | |
| Total malignant | | 101 | (47%) |
| Granuloma | | 82 (38.1%) | |
| Hamartoma | | 9 | |
| Pleural mesothelioma | | 6 | |
| Chronic pneumonitis | | 4 | |
| Bronchogenic cyst | | 3 | |
| Bronchopulmonary sequestration | | 3 | |
| Neurofibroma | | 2 | |
| Chronic lung abscess | | 2 | |
| Lipoid granuloma | | 1 | |
| Hyperplastic lymph node | | 1 | |
| "Aspergilloma" | | 1 | |
| Total benign | | 114 | (53%) |

Of our 215 patients personally operated upon, 101 (47 per cent) had malignant lesions. Ten of these were metastatic but the remaining 91 (42 per cent) were primary pulmonary neoplasms. Nine were bronchial adenomas which, in keeping with their malignant propensities, have been classified with the malignant tumors. The remainder include 79 bronchogenic carcinomas, one fibrosarcoma, one leiomyosarcoma, and one lymphoblastoma.

Of the benign nodules more than two thirds were granulomas (see Table VIII). Wherever possible the tissue blocks from these cases have been resectioned and meticulously studied by Ziehl-Neelsen, periodic acid-Schiff, and Gridley stains. In this way it has been possible to establish a specific etiology in four fifths of the cases. Histoplasma have been demonstrated in over one half of all granulomas so studied. Coccidioides were found in 5 cases and

tubercle bacilli in 12. Two of the latter cases actually represented blocked tuberculous cavities and *M. tuberculosis* was easily recovered in culture. Despite exhaustive examination, no organisms could be identified in 12 cases and these have been properly labeled nonspecific. Tissue was no longer available in 15 cases and these are classed simply as granulomas.

There are 17 benign tumors in the series. The most common benign tumor in our group, and this has also been true of combined reported series (see Table II), is the hamartoma. We have excised 9 hamartomas, 2 of them from one patient in operations spaced five years apart. In our experience, pleural mesotheliomas frequently give the impression radiographically of an intrapulmonary location. On six occasions we have operated for solitary pulmonary tumors only to find mesotheliomas. Earlier in our experience these were classified as fibromas. Two intrapulmonary neurofibromas complete the list of benign tumors.

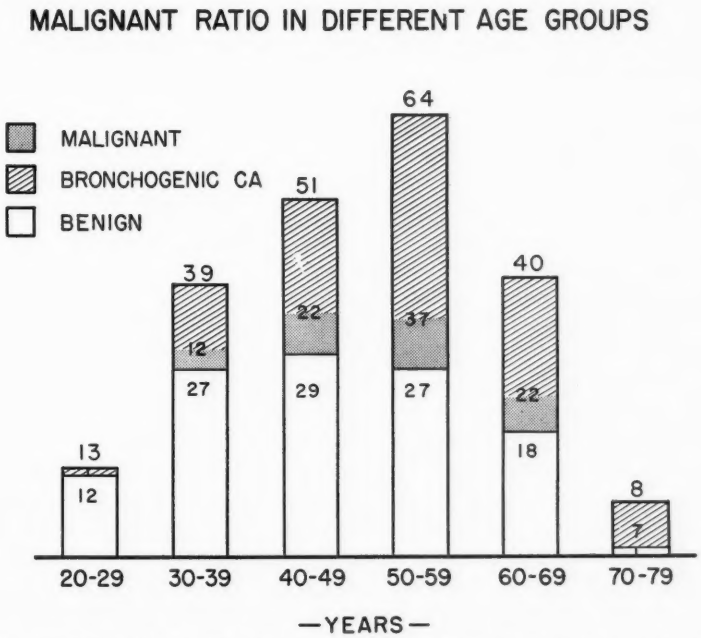



Fig. 1.—Distribution of 215 solitary pulmonary nodules; malignant versus benign.

Bronchogenic cysts were encountered six times and 3 of these, all located in the right lower lobe, proved to be examples of bronchopulmonary sequestration.

In our figures are included several vague types of inflammation such as chronic pneumonitis, four times, a chronic lung abscess, twice. A careful search was made for an etiologic agent compatible with their indolent character but none could be demonstrated. One patient with lipoid granuloma is in-

eluded who has been reported elsewhere.[53] The other patients represented unusual conditions, one with a hyperplastic lymph node in the periphery of the lung, another a healed tuberculous cavity filled with a "fungus ball," the so-called "aspergilloma."

TABLE III. AGE AND SEX DISTRIBUTION OF 215 SOLITARY PULMONARY NODULES

| LESION | TOTAL CASES | MEN | WOMEN | AGE, YEARS | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 20 TO 29 | 30 TO 39 | 40 TO 49 | 50 TO 59 | 60 TO 69 | 70 TO 79 |
| Bronchogenic carcinoma | 79 | 64 | 15 | -- | 9 | 16 | 30 | 17 | 7 |
| Bronchial adenoma | 9 | 5 | 4 | 1 | 1 | 2 | 3 | 2 | -- |
| Primary sarcoma | 2 | 2 | -- | -- | -- | -- | 2 | -- | -- |
| Lymphoblastoma | 1 | -- | 1 | -- | 1 | -- | -- | -- | -- |
| Metastatic tumor | 10 | 5 | 5 | -- | 1 | 4 | 2 | 3 | -- |
| Total malignant | 101 | 76 | 25 | 1 | 12 | 22 | 37 | 22 | 7 |
| Granuloma | 82 | 40 | 42 | 9 | 22 | 19 | 19 | 13 | 0 |
| Hamartoma | 9 | 5 | 4 | 1 | -- | 4 | 3 | -- | 1 |
| Pleural mesothelioma | 6 | 2 | 4 | -- | 2 | 2 | 2 | -- | -- |
| Chronic pneumonitis | 4 | 4 | -- | -- | -- | 2 | -- | 2 | -- |
| Bronchogenic cyst | 3 | 1 | 2 | -- | -- | -- | 2 | 1 | -- |
| Bronchopulmonary sequestration | 3 | 1 | 2 | -- | 2 | -- | 1 | -- | -- |
| Neurofibroma | 2 | 2 | -- | 2 | -- | -- | -- | -- | -- |
| Chronic lung abscess | 2 | 2 | -- | -- | 1 | -- | -- | 1 | -- |
| Lipoid granuloma | 1 | -- | 1 | -- | -- | -- | -- | 1 | -- |
| Hyperplastic lymph node | 1 | 1 | -- | -- | -- | 1 | -- | -- | -- |
| "Aspergilloma" | 1 | 1 | -- | -- | -- | 1 | -- | -- | -- |
| Total benign | 114 | 59 | 55 | 12 | 27 | 29 | 27 | 18 | 1 |

The age and sex distribution of our cases are indicated in Table III. The youngest patient was 20 years old; the oldest, 76. As one might predict, the patients with bronchogenic carcinoma were somewhat older than those with other lesions. However, the difference was not as great as in other series. For instance, in two reported series in which solitary nodules were subdivided according to age of the patient,[11, 15] there was a total of 52 patients with bronchogenic carcinoma only one of whom was less than 40 years of age. In our group of 79 patients with bronchogenic carcinomas, 9 were in the 30- to 39-year age group, the youngest being 32. In keeping with reports of the type of bronchogenic carcinoma seen in young people,[54, 55] there was a disproportionately large number of undifferentiated and adenocarcinomas, only 2 of the 9 being squamous carcinomas. In the same age group, our series contains 3 other malignant tumors making a total of 12 malignant tumors as opposed to 27 benign nodules in patients of comparable age. To us this is an extremely important finding, for some have held that the chance of malignancy in solitary nodules in patients less than 40 years of age is practically nil. In our experience the possibility of a nodule being malignant in the 30- to 39-year age group is almost one in three. In the 40- to 49-year age group the chance of malignancy was practically 50 per cent and it was substantially higher in the older groups. Patients with bronchial adenoma had essentially the same age distribution, although 2 of these, ages 27 and 30, represent the youngest patients with malignant tumors in this series.

The distribution of the benign lesions in the various age groups was as expected. The granulomas were fairly evenly distributed with the largest number, 22, occurring in the 30- to 39-year group. Of some significance perhaps is the fact that in the 20- to 29-year group, a very high percentage of patients, 9 out of 13, had granulomas. The oldest patient who had a benign tumor removed (a hamartoma) was a man aged 74. The remainder of the benign nodules were too few in number and too evenly distributed to be of any statistical significance.

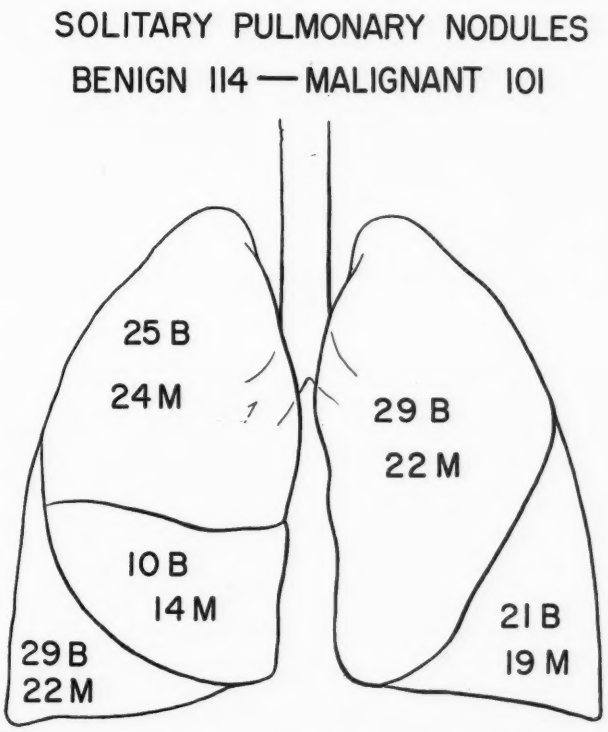



Fig. 2.—Graph illustrating the percentage of malignant nodules among different age groups. In the older patients the ratio was over 50 per cent but, even in the decade 30 to 39 years, almost one nodule in three was malignant, a forceful argument against those who contend that the chance of malignancy is remote in those under 40 years of age.

The sex distribution was as anticipated. Out of the entire series only 81 (37.6 per cent) were women. Among the granulomas there was almost an even breakdown between women (42) and men (40) and the same was true of the bronchial adenomas (4 out of 9 being women), metastatic tumors (5 out of 10 being women), and hamartomas (4 out of 9 being women). There was a predominance of females among the patients with pleural mesotheliomas (4 out of 6 being women), bronchogenic cysts (2 out of 3 being women), and bronchopulmonary sequestration (2 out of 3 being women), but in those with

bronchogenic carcinomas 64 out of 79 (81 per cent) were men. Needless to say, in any given case the patient's sex is of no significance so far as the possibility of malignancy is concerned.

The lobar distribution of the nodules, as shown in Fig. 2, was fairly even with no great difference between the malignant and benign tumors. Since all cases represented circumscribed peripheral lesions, location likewise appeared to have no effect on prognosis.

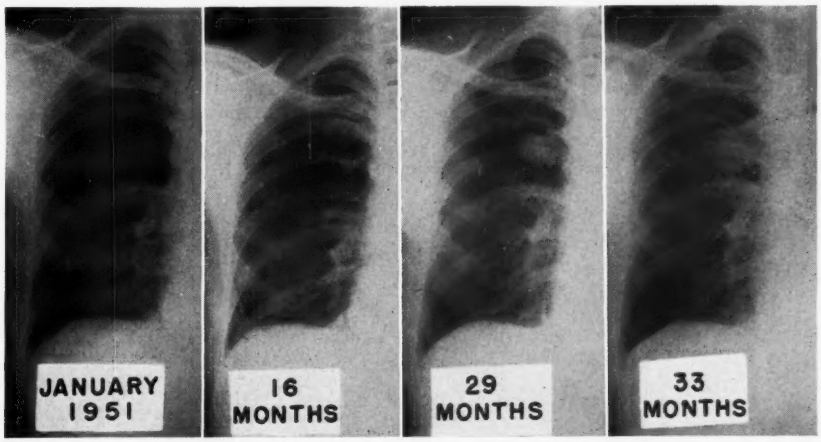
Symptoms, their presence or absence and their significance, are difficult to evaluate in the patient with a solitary pulmonary nodule. Most of our patients claimed to have no symptoms on initial questioning, yet upon close interrogation a number admitted a slight cough. Percentagewise this was a more common finding in the patient with bronchogenic carcinoma (Table IV).

TABLE IV. SYMPTOMS ASSOCIATED WITH 215 SOLITARY PULMONARY NODULES

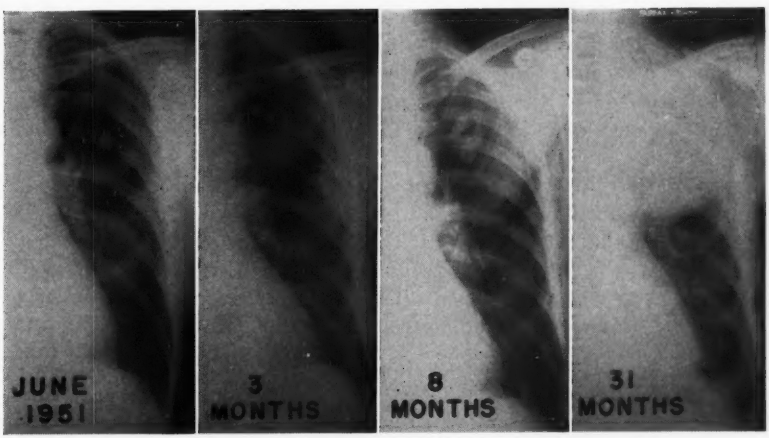
| LESION | TOTAL CASES | ASYMPTOMATIC | COUGH | HEMOPTYSIS | CHEST PAIN | ARTHRITIS |
|---|---|---|---|---|---|---|
| Bronchogenic carcinoma | 79 | 42 | 21 | 8 | 5 | 3 |
| Bronchial adenoma | 9 | 7 | -- | 1 | 1 | -- |
| Primary sarcoma | 2 | 2 | -- | -- | -- | -- |
| Lymphoblastoma | 1 | 1 | -- | -- | -- | -- |
| Metastatic tumor | 10 | 8 | 1 | -- | 1 | -- |
| Malignant nodules | 101 | 60 | 22 | 9 | 7 | 3 |
| Granuloma | 82 | 73 | 9 | -- | -- | -- |
| Hamartoma | 9 | 9 | -- | -- | -- | -- |
| Pleural mesothelioma | 6 | 6 | -- | -- | -- | -- |
| Chronic pneumonitis | 4 | 1 | 1 | 2 | -- | -- |
| Bronchogenic cyst | 3 | -- | 3 | -- | -- | -- |
| Bronchopulmonary sequestration | 3 | 3 | -- | -- | -- | -- |
| Neurofibroma | 2 | 2 | -- | -- | -- | -- |
| Chronic lung abscess | 2 | 1 | 1 | -- | -- | -- |
| Lipoid granuloma | 1 | 1 | -- | -- | -- | -- |
| Hyperplastic lymph node | 1 | 1 | -- | -- | -- | -- |
| "Aspergilloma" | 1 | -- | 1 | -- | -- | -- |
| Benign nodules | 114 | 97 | 15 | 2 | -- | -- |

It should be recognized, however, that 25 patients with bronchogenic carcinoma were observed for periods ranging from one to eight years before being referred to us for surgical consultation. Of these, a certain number had been asymptomatic when the nodule was originally discovered but developed symptoms while under "observation" (Fig. 3, *A* and *B*). Other patients developed symptoms after being told that their x-ray showed a pulmonary lesion. This was particularly true of chest pain which in many instances was of such a vague or fleeting nature that it was not considered worth recording. If on the other hand, the patient complained of clear-cut, persistent chest pain, as did 6 patients in this series, it invariably indicated a malignant lesion. Actually from their subpleural location and rather constant evidence of associated pleural thickening, the granulomas might be expected to cause pain. The Mayo group[11] stated that, out of 65 patients with granulomas in their series, 12 had some degree of chest pain. This has not been true in our experience and we cannot help but suspect that their report must have included instances of mild, momentary pains that we tend to disregard.

Among our patients, hemoptysis was another symptom having diagnostic significance. Eleven of our patients had coughed up blood in varying quantities, the sputum usually being only blood streaked. Eight of these patients




*A.*




*B.*

Fig. 3.—Serial roentgenograms of 2 patients with solitary pulmonary nodules neglected for prolonged periods of time. *A*, Despite a delay of almost three years before operation, this patient is alive and well more than three years postoperatively, even though the extent of tumor required excision of portions of the superior vena cava and trachea. *B*, The second patient represents the more common situation wherein, after a comparable delay, the tumor is unresectable.

proved to have bronchogenic carcinoma and another a bronchial adenoma, while among those with benign lesions, there were only 2 patients with hemoptysis, both having a chronic nonspecific type of pneumonitis. One other symptom was most dramatic when it occurred and in this series was indicative of a malignant lesion. This was severe arthralgia involving one or more joints

with associated clubbing of the digits. It is well known, of course, that such symptoms not infrequently are associated with bronchogenic carcinoma, and that they are much more commonly associated with peripheral lesions,[56] especially when there is pleural involvement.[57] Three of our patients had severe arthralgia and all 3 had bronchogenic carcinoma. One was invading the pleura, the other two were immediately subpleural in location. None of our pleural mesotheliomas were accompanied by pulmonary osteoarthropathy which is surprising, since this tumor is supposed to have the highest associated incidence of arthralgia and clubbing,[57, 58] although in total frequency, of course, it ranks second to bronchogenic carcinoma. In our experience, the occurrence of arthralgia in association with bronchogenic carcinoma has an unfavorable prognosis, all 3 of our patients with this finding now being dead.

## DIAGNOSTIC CONSIDERATIONS

Easily the outstanding characteristic of the solitary pulmonary nodule is the failure to establish its nature by any means other than thoracotomy. We would be remiss, however, if no more than this were said.

*History.*—The history is rarely of help in establishing a preoperative diagnosis and may actually be quite misleading. Take, for example, the patient who has been known to have tuberculosis and subsequently develops a solitary pulmonary nodule. Although it may be tempting and certainly logical to presume that it is tuberculous, blind adherence to a program of medical management can be disastrous in such a situation. A history of previous cancer surgery may also provide a clue to the etiology of the pulmonary lesion, although on occasion it will prove completely fallacious. This is well demonstrated in our series by 3 patients with a history of having had a malignant tumor elsewhere all of whom proved at operation to have primary bronchogenic carcinomas. As a general rule, however, one is perfectly right in inferring from such a history that the pulmonary nodule is a metastatic lesion. Even so, in any individual case it must constantly be borne in mind that the lesion in the lung may be unrelated to the malignant tumor elsewhere. This is especially true when the period of time between previous surgery and the detection of the pulmonary nodule is relatively long.

*Laboratory Examinations.*—Routine laboratory studies were of no diagnostic value. Several authors have commented on the significance of an elevated sedimentation rate in these patients, one group feeling that, in the patient with neoplastic disease, the sedimentation rate is elevated often enough to be of serious import[11] while another group was unable to show a very prominent difference in sedimentation rates between those with benign and malignant disease.[32] As far as we are concerned there is no advantage in having sedimentation rates in these patients.

*Skin Tests.*—Although we have found a perfect correlation so far between the positivity of specific skin tests and the identification of acid-fast bacilli, Histoplasma, and Coccidioides in resected granulomas, we have not found these tests to be of diagnostic significance preoperatively except when all are

negative, in which event the chance of malignancy is increased. As a matter of fact, in any patient with a solitary pulmonary nodule, no matter how benign it may appear, the demonstration of negative tuberculin, histoplasmin, and coccidioidin skin tests adds even greater urgency to the need for resection. Preoperatively this is the chief value of skin tests but, in addition, after a grossly granulomatous process has been excised, the skin tests may be of considerable help in limiting the etiological possibilities and suggesting which staining methods are apt to be most productive.

*Bacteriologic Examination of Sputum.*—Bacteriologic studies of the sputum were of little aid in diagnosis. Of those patients whose lesions ultimately proved to be tuberculous, numbering 12 in all, none were diagnosed preoperatively. Concentrated sputum smears were uniformly negative for acid-fast bacilli in the 8 patients in whom such studies were obtained. Two patients had a positive culture for *M. tuberculosis* returned postoperatively. Considering first, the low yield of sputum cultures in encapsulated tuberculous foci, second, the advisability of surgical resection of most such foci anyway and finally, and most important of all, in view of the urgency of operation for the indistinguishable cases of carcinoma, there is seldom any justification for delaying operation until the reports of sputum cultures return. Also, as pointed out by Waterman,[59] there is considerable hazard in placing extreme faith in a report of acid-fast bacilli in the sputum when the question of malignancy is being considered. For example, 4 of our patients with bronchogenic carcinoma had been observed for periods ranging from one to three years because of a positive sputum smear or culture for acid-fast bacilli. Two of these patients had tuberculosis and carcinoma in combination, but no tuberculous element was discernible in the resected specimens of the other 2 patients nor did either show clinical evidence of tuberculosis postoperatively. These are considered to be false positive reports of acid-fast bacilli, a possibility too little appreciated and too frequently a cause of delay and ultimate inoperability.

*Cytologic Examination of Sputum.*—The Mayo Clinic report[11] has stressed the value of cytologic examination of the sputum in the preoperative work-up of patients with solitary nodules. In 15 patients with peripheral circumscribed bronchogenic carcinomas, malignant cells could be demonstrated in sputum preparations of 8 (53 per cent). A smaller percentage (23.75 per cent) of a larger series of carcinomas (59 cases) included in the report by Ford and his associates[32] showed cancer cells in the sputum. On the other hand, Wilkins[15] found malignant cells in the sputum of only 3 patients out of 32 with bronchogenic carcinoma who had Papanicolaou studies of their sputum, and one of these turned out to be a false positive report.

Our own feeling, based on an experience similar to Wilkins', is that the value of malignant cell studies is seriously limited by the complete unreliability of a negative report, the occasional unreliability of a positive report and the failure of either a positive or negative report to alter the decision to operate. This last statement might be modified of course in the extremely poor-risk patient in whom operation might be justified only by overwhelming evidence

of a malignant lesion. In the management of the solitary pulmonary nodule, we have not been putting private patients to the expense of cytologic studies of the sputum.

*Bronchoscopy.*—One would hardly expect bronchoscopy to be of diagnostic value in a peripherally situated solitary pulmonary nodule. This proved true in practice and for the past eight years we have seldom seen an indication for bronchoscoping these patients, unless the lesion lies in the vicinity of the hilus.

*Roentgenography.*—Inasmuch as this lesion is essentially a radiographic one, it is logical that the most elaborate attempts at diagnosis should be along roentgenologic lines. Many points deserve discussion.

a. *Size:* Size somewhat influences the ratio of benign to malignant nodules in that the smaller nodule is more apt to be benign and the larger nodule more apt to be malignant but, in the individual case, size is no guide to the etiology or biologic activity of a nodule. For example, three bronchogenic carcinomas in our series were 1 cm. or less in diameter when originally detected. Twenty-nine others were 3 cm. or less in diameter, while 41 were between 3 and 5 cm. in diameter, another 6 being 6 cm. in diameter. By comparison there were only 4 granulomas that were 5 cm. in diameter. As Fig. 4 illustrates, though, one can be badly deceived if size is used as a guide to management. Regardless of size we feel that any solitary uncalcified pulmonary nodule should be excised.

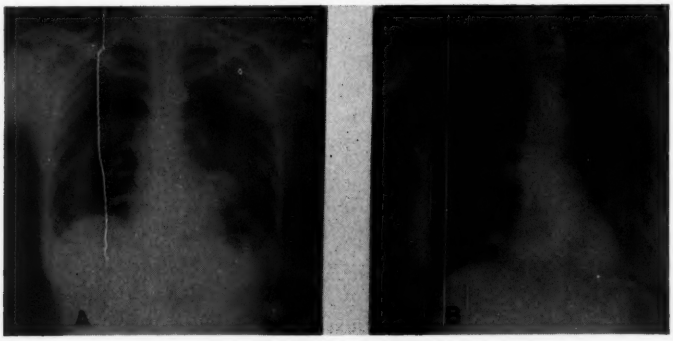


Fig. 4.—Roentgenograms showing the fallibility of size as a guide to diagnosis. The large 5.5 cm. nodule in patient *A* was a histoplasmoma. The small one cm. nodule in the left mid-lung field of patient *B* was an adenocarcinoma.

b. *Sharpness of margin:* Again no rules can be established, for some of the benign nodules in our series have had somewhat hazy borders just as some of the malignant ones have been perfectly smooth, round, and very sharply marginated. In general, however, the benign tumors did tend to have better defined borders, but the difference was slight even on a statistical basis. Most radiologists agree that it is impossible to differentiate benign from malignant nodules on the basis of size or margination and is no better demonstrated than in a comparison of some of the nodules included in our series (Figs. 5 through 9).

c. *Umbilication of margin ("notch sign"):* Attention has recently been directed to the value of an indentation or umbilication of the border of a solitary nodule as a sign of malignancy, the so-called "notch sign" of Rigler.[35, 60]

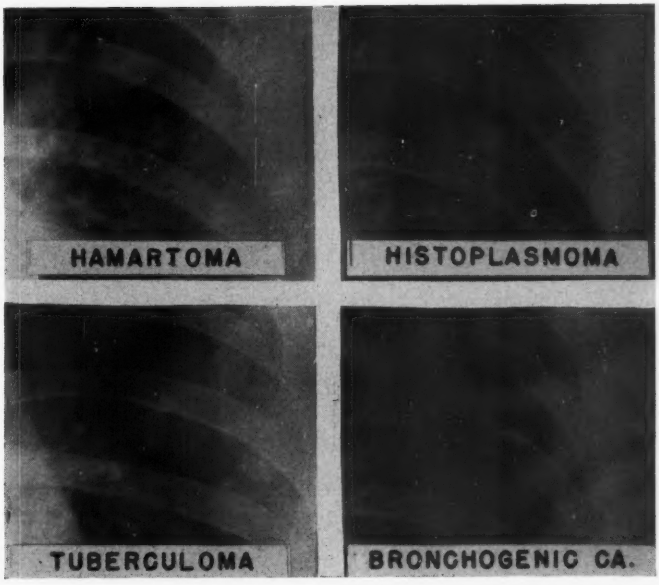



Fig. 5.

Figs. 5–9.—Comparative x-rays of nodules of similar size and location but different etiology. Obviously, to attempt a clinical differentiation between the benign and malignant nodules is virtually impossible.

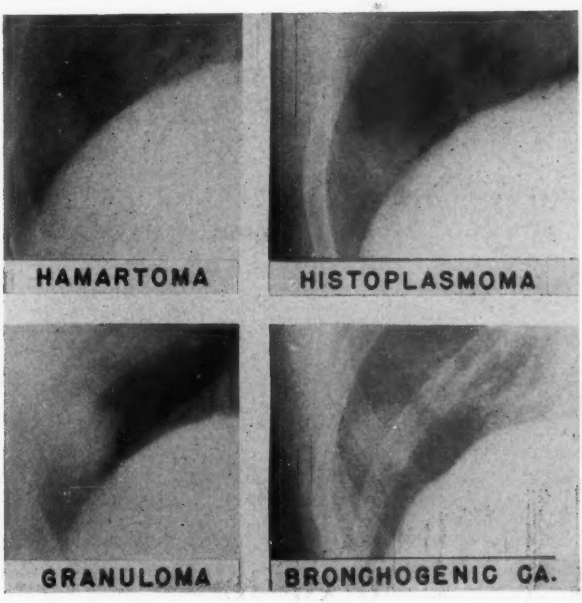



Fig. 6.

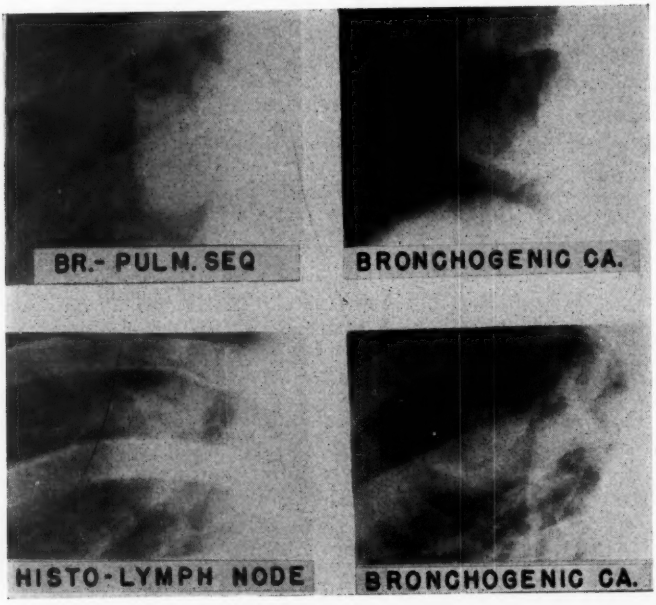

BR.- PULM. SEQ
BRONCHOGENIC CA.
HISTO-LYMPH NODE
BRONCHOGENIC CA.

Fig. 7.

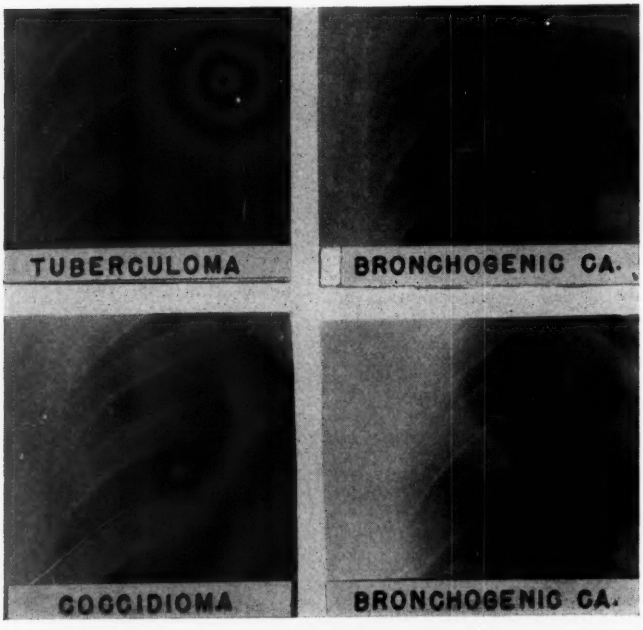

TUBERCULOMA
BRONCHOGENIC CA.
COCCIDIOMA
BRONCHOGENIC CA.

Fig. 8.

It has been impossible to analyze this radiographic feature in our entire series, although we have seen at least 4 cases, all of them malignant, in which a "notch sign" was clearly seen. Less distinctive notches were seen in two granulomas. Rather than argue the reliability of this sign we prefer to question its value as a guide to therapy, inasmuch as the cases in which it is positive usually rate excision anyhow. A truly practical roentgenologic aid would be one that might spare the patient unnecessary surgery.

d. *Recent origin:* One feature strongly suggesting malignancy is the demonstration of recent origin of the nodule. This is contingent of course upon recent x-rays being available showing the appearance of the nodule within a matter of months. This is rarely possible but does constitute good evidence of malignancy when found.

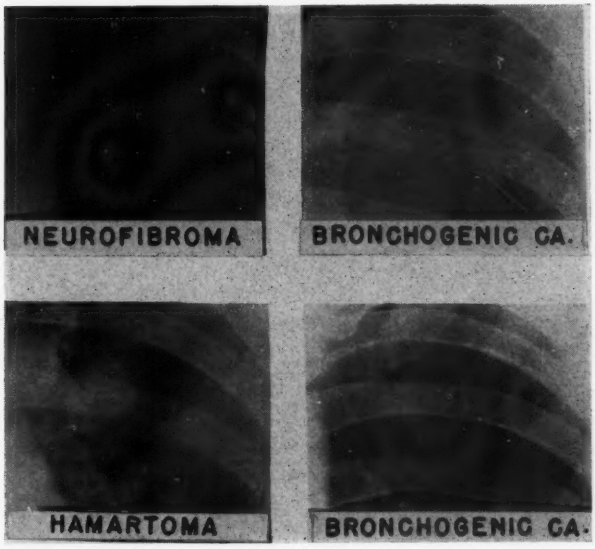



Fig. 9.

e. *Growth:* An enlarging pulmonary nodule is more apt to be malignant and even more so if the enlargement is rapid. Fig. 10 indicates the variability of this sign, however, as shown by rapid enlargement of a coccidioma within the space of two months as compared with no greater enlargement of an adenocarcinoma of the lung transpiring over a two-year span. It is really amazing how imperceptible may be the growth of carcinomas over a prolonged period. One of our patients with an undifferentiated bronchogenic carcinoma presented a nodule that did not appear to enlarge during eight years of preoperative observation, then began to show radiographic evidence of concentric enlargement. There was no evidence in the specimen of an underlying adenoma nor any pre-existing inflammatory process, nothing but undifferentiated carcinoma.

Obviously then, one can be deluded by an apparently stable lesion and we would prefer to have x-rays showing no change going back at least five years before we would agree that observation should continue. The real indictment of a program of "watchful waiting," therefore, rests not alone on the fact that carcinomas may become inoperable in the time between examinations, but more basically than that, upon the erroneous inference that growth necessarily means a malignant lesion or that a lack of growth is any assurance against malignancy.

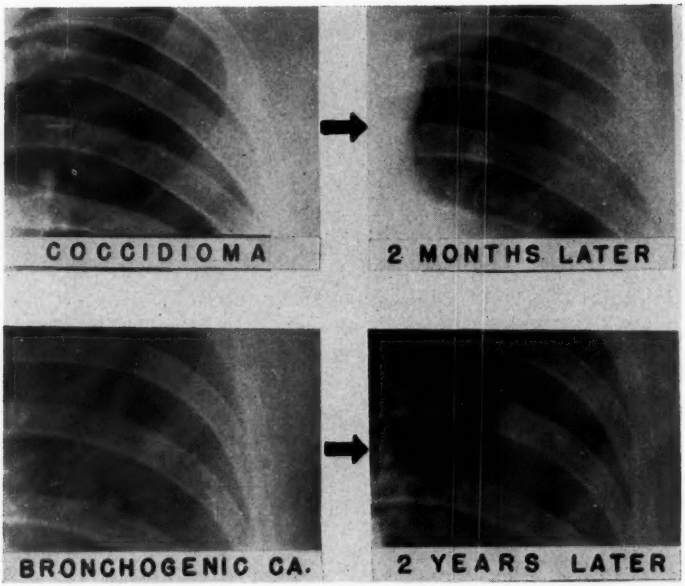



Fig. 10.—Serial roentgenograms showing the unreliability of growth as an indication of malignancy. Both lesions shown were about one centimeter in diameter when initially detected. The coccidioma grew three times its original size within a 2-month period, whereas the carcinoma took more than two years to enlarge to the same degree.

f. *Density:* After carefully analyzing our cases we feel that certain generalizations, none of them absolute, can be drawn from the density of a pulmonary nodule. Those under 2 cm. and dense are usually granulomas while those of similar size but not dense can be either granulomas or carcinomas. Those over 2 cm. and dense can be either granulomas or carcinomas while those of similar size but not dense are probably carcinomas. This point has been stated slightly differently by others,[61] namely, all lesions of medium or small size (less than 3 cm.) of light density should be considered malignant; small lesions of heavy density are less likely to be malignant; as the medium-sized lesions of heavy density approach 3 cm. in size, suspicion of malignancy should rise accordingly. Although such information is helpful in analyzing individual cases, it is hardly reliable enough to dictate policy in the management of these nodules.

g. *Calcification:* We have long contended, as have others,[21, 22, 62-65] that the solitary pulmonary nodule containing radiographic evidence of calcification

is so consistently benign that it need not be excised unless serial x-rays show signs of instability. Obviously, for it to serve as a guide the presence of calcium must be unequivocal, it must not be just one of many calcific deposits and it must be shown to lie within and not adjacent to nor superimposed upon the nodule. We have occasionally heard the complaint that the preoperative impression of calcification does not always correlate with pathologic examination of the specimen. In our experience the correlation has been completely reliable, an indication perhaps of our strict requirement so far as the presence of calcium is concerned. If there is any question as to the presence of calcium, we have considered the lesion to be noncalcified and treated it accordingly. At the same time we are in complete agreement with Bloch[66] who found in a beautifully conducted study that the absence of radiographically visualized calcium, in fact the lack of a pronounced degree of radiographic density, does not exclude the presence of fairly abundant calcification. This is well seen in Fig. 11 wherein a histoplasmoma and hamartoma, neither of which showed calcification in tomograms, were shown to contain considerable calcium in x-rays of the specimen. Even then there are those who take vigorous exception to its validity as a sign of benignity.[6, 23, 26, 28, 67] Be that as it may, in a fairly extensive experience with completely and partially calcified pulmonary nodules, we have routinely advised medical observation and have never had cause to regret it. Of innumerable nodules so followed, 3 subsequently displayed concentric enlargement and were then excised, one proving to be a tuberculoma, one a histoplasmoma (Fig. 12), and one a nonspecific granuloma. None of the others have shown signs of reactivation or malignancy (Table V).

TABLE V. PARTIALLY CALCIFIED PULMONARY NODULES SURGICALLY EXCISED BY US

| TYPE OF CALCIFICATION | REASON FOR RESECTION | PATHOLOGIC DIAGNOSIS |
|---|---|---|
| 1. Concentric laminations | Physician's insistence | Nonspecific granuloma |
| 2. Central core | Concentric enlargement | Nonspecific granuloma |
| 3. Inner ring | Patient's insistence | Histoplasmoma |
| 4. Large central core | Patient's insistence | Histoplasmoma |
| 5. Inner ring | Concentric enlargement | Histoplasmoma |
| 6. Central core | Physician's insistence | Histoplasmoma |
| 7. Central core | Patient's insistence | Histoplasmoma |
| 8. Central core | Patient's insistence | Histoplasmoma |
| 9. Diffuse conglomerate | Concentric enlargement | Tuberculoma |
| 10. Central core | Physician's insistence | Granuloma |
| 11. Eccentric flecks | Question of carcinoma | Hamartoma |
| 12. Eccentric flecks | Question of carcinoma | Bronchogenic carcinoma (squamous) |

Recently, however, we were disturbed to have a small right apical nodule in which x-rays showed several calcific flecks turn out to be a primary squamous carcinoma of the lung[68] (Fig. 13). A review of the literature indicates that this is an extremely rare occurrence. In 1953, Good,[64] in a wide radiologic experience at the Mayo Clinic, claimed never to have seen a malignant solitary pulmonary nodule containing radiographically demonstrable calcium. In the discussion following his paper, however, Hodes made reference to 4 patients with partially calcified nodules that were ultimately found to be malignant and Riemenschneider cited a solitary nodule showing roentgenographic evidence of calcification which proved pathologically to be

a granuloma with a nodule of bronchial carcinoma in its wall. Prior to this the only similar case of which we are aware was one alluded to by Tuttle,[67] but since then several other instances have been reported.[13, 23,* 69,* 70] Moreover, Liebow has demonstrated microscopic calcification in still another.[71] In order to assess the true incidence of this occurrence we thought it advisable to poll the members of The American Association for Thoracic Surgery for, as far as we are concerned, resolution of this question is one of the most important problems confronting thoracic surgeons.

Fig. 11.—X-rays of two resected specimens showing both to contain relatively large amounts of calcium which in preoperative tomograms escaped detection. Repeated examples such as these emphasize that tomograms, because they tend to underestimate rather than exaggerate the amount of calcification, are ordinarily quite reliable when positive.

Fig. 12.—The solitary nodule shown in *A* was first picked up in 1952 in a routine chest x-ray. Tomogram (*B*) demonstrated a ring of calcium within the nodule. Histoplasmin skin test was positive. The patient was followed by serial roentgenograms until 1955 when the nodule increased in size (*C*) and was therefore resected. The PAS stain proved it to be a histoplasmoma.

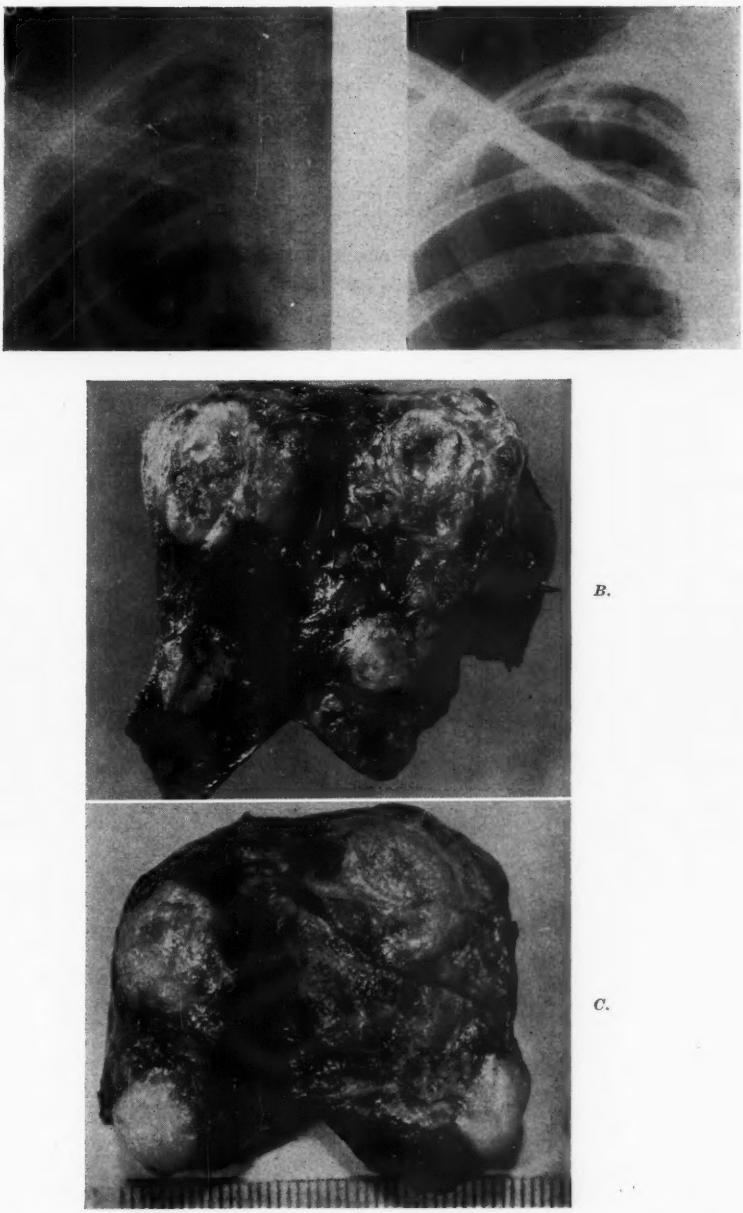
Questionnaires were sent to 452 members of the Association, 9 of whom had died or could not be found. Of the remaining 443, answers were received from 328 (74 per cent).

QUESTION No. 1. In handling the partially calcified solitary pulmonary nodule my usual policy is: Resection ☐ Observation ☐.

| | | |
|---|---|---|
| Answers: | Resection | 143 |
| | Observation | 146 |
| | Individualize | 7 |
| | Undecided | 32 |
| | Total | 328 |

*Comment:* Opinion evenly divided between observation and resection.

*References 23 and 69 relate to the same case.



A.

B.

C.

**Fig. 13.**—*A*, Comparative reontgenograms of 2 patients with lesions of contrasting etiology but remarkably similar appearance. From their apical location both resemble tuberculomas, especially the one on the right since it contains several calcific flecks. Although the nodule above (*B*) did consist of conglomerate tubercles from which acid-fast bacilli were recovered, that below (*C*), almost identical in its gross appearance, proved to be a squamous carcinoma of the lung. Thus, minimal calcification is not a justifiable basis for observing a solitary nodule.

QUESTION No. 2. Do a few flecks of calcium within the nodule provide adequate assurance of benignity?

| | | |
|---|---|---|
| Answers: | Yes | 46 |
| | No | 250 |
| | Undecided | 32 |
| | Total | 328 |

*Comment:* Opinion overwhelmingly against the reliability of a few flecks of calcium as an indication of benignity. Same 32 members still undecided.

QUESTION No. 3. Have you ever encountered in your personal experience a malignant solitary pulmonary nodule containing calcium? Yes ☐ No ☐. If so, how many?

| | | |
|---|---|---|
| Answers: | Yes | 114 |
| | No | 203 |
| | Don't know | 11 |
| | Total | 328 |

How many? Answers varied from "one" (by far the majority) to "twelve" (William Weisel) to "too many" (Edward O'Brien).

QUESTION No. 4. If your answer to Question 3 is affirmative, briefly elaborate on the size of the tumor, cell type, and the amount and distribution of the calcium.

*Comment:* Of the 114 members who had encountered a malignant solitary pulmonary nodule containing calcium, 76 provided a brief detailed report of 155 cases. One was described as 6 cm. in diameter, one as 5 cm. and the rest, one to 4 cm. Breakdown by cell type is enumerated in Table VI.

TABLE VI. ANSWER TO QUESTIONNAIRE
MALIGNANT SOLITARY NODULES CONTAINING CALCIUM
155 CASES—76 SURGEONS

| CELL TYPE | NUMBER |
|---|---|
| Squamous | 69 |
| Adenocarcinoma | 28 |
| Undifferentiated | 10 |
| Metastatic | 6 |
| Adenoma | 6 |
| Bronchiolar | 2 |
| Oat-cell | 2 |
| Sarcoma | 2 |
| Malignant hamartoma | 2 |
| Hemangiopericytoma | 1 |
| Not stated | 27 |
| | 155 |

The frequency with which partially calcified malignant nodules were reported was quite surprising to us. In analyzing these cases, however, it soon became apparent that the majority were minimally calcified, most containing one or several "flecks" which when described in detail were generally "small" or "tiny." In but one instance were the flecks of calcium described as "large" (Tyson). Most such flecks were eccentrically situated often being referred to as "marginal" or "peripheral." In only 13 cases was the calcific

deposit described as centrally situated and in none of these was the calcification large enough to be called a central core. There were, on the other hand, a few instances in which more extensive calcification was reported. These included a 2 cm. adenocarcinoma with "moderate central calcification" (Daughtry), a baseball-sized squamous carcinoma with "marked calcification irregularly dispersed throughout" (Mangiardi), a 5 cm. adenocarcinoma with "extensive calcification" (Harkin), and a 4 cm. "completely calcified" bronchial adenoma (Rosemond). Of Weisel's 12 cases, 10 of which were squamous and 2 adenocarcinomas, the calcification varied from "scanty to plentiful" and somewhat the same was true of Thompson's 4 cases in which the amount of calcium varied from "heavy to light." In none of the cases described was the calcium deposited in the form of a ring or concentric laminations, although one such lesion, a 6 by 5 by 4 cm. adenocarcinoma, was said to have a "calcified capsule" (Hausman). Scattered flecks were mentioned several times but none of these malignant nodules were said to present a diffusely stippled-type calcification.

Of considerable interest was the answer of Dr. C. Allen Good of the Mayo Clinic who, as mentioned earlier, has long been a strong proponent of conservatism in the handling of the partially calcified solitary pulmonary nodule. Like ourselves he has recently encountered a peripheral bronchogenic carcinoma presenting an eccentrically situated nidus of calcium, a case recently reported.[72] Even more significant perhaps was his report of a study carried out by O'Keefe of their clinic who analyzed roentgenologically the specimens of some 200 resected solitary nodules. After enucleating each nodule from the surrounding lung substance, he was able to show evidence of calcification in 10 per cent of the bronchial carcinomas. In some instances it occurred in areas of necrosis, while in others it seemed to represent postinflammatory fibrocalcific deposits that had been engulfed by tumor. Good concluded:

"While I still believe, as I have stated in several articles, that calcification is usually a sign that the lesion is not malignant, I must admit that I must qualify this belief in the light of the facts available to me. I still believe that we can regard as benign the lesion which is calcified in a laminated fashion or which looks like a 'target.' I also believe that any mass which shows evidence of a large amount of calcium is undoubtedly benign. On the other hand, I think we must be more careful of the lesion which shows a very small central or eccentric nidus or which is only very slightly calcified."

As a result of this survey we too are convinced that the presence of minimal calcification within a solitary pulmonary nodule, especially when it is no more than a small fleck, is unjustifiable grounds for assuming it to be benign. These we now resect unless there are old films available, preferably four to five years earlier, showing the lesion to be unchanged in size and configuration. On the other hand, when dealing with lesions containing a moderate amount of calcium, it would seem fair to be much more conservative. Those that contain a relatively large central core of calcium, those that present concentric laminations, an inner ring or an outer rim of calcium and those that are dif-

fusely stippled or completely calcified are almost assuredly granulomas and can be left alone (Fig. 14). Even then, any increase in size of the lesion should be a cause for alarm regardless of the presence or amount of calcium.

h. *Cavitation:* Lesions that were cavitary when initially detected have been purposefully excluded from this study, first, because the many terms applied to these small radiographic densities, such as, nodule, coin lesion, etc., all imply that the lesion looks solid; second, because their inclusion, like the inclusion of calcified nodules, would weight the statistics in favor of the benign nodule; and finally because the indication for surgery is probably more universally accepted in the case of the cavitary lesion. On the other hand, several

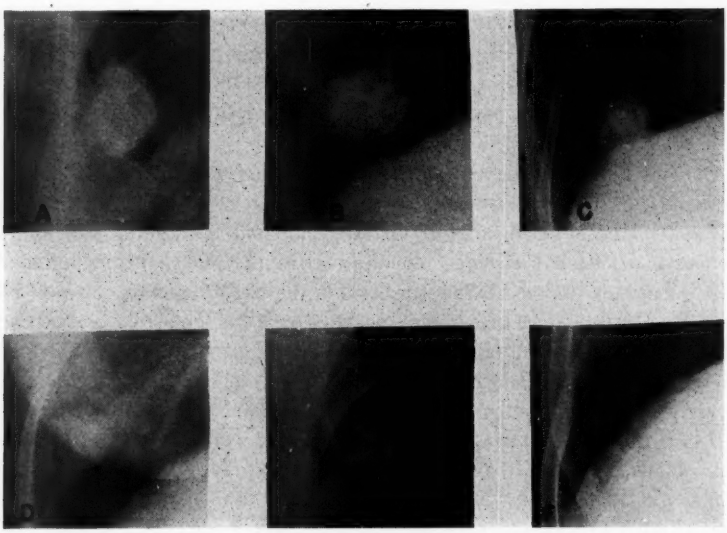


Fig. 14.—Representative plain x-rays of various types of calcification that we consider grounds for observation. *A*, Solidly calcified nodule. *B*, Diffusely calcified nodule. *C*, Nodule with a large calcific core and concentric laminations. *D*, Nodule with an extremely large central core of calcium. *E*, Nodule with a large eccentric core of calcium. *F*, Nodule with a moderately large central nidus of calcium. When calcification of these types and prominence is demonstrable, we leave the nodule alone unless it increases in size or shows other evidence of instability.

nodules are included that were initially solid but showed signs of central necrosis while under observation. Two of these were tuberculomas that excavated but were easily treated by resection plus long-term antituberculous chemotherapy. One was an Aspergillus-packed lung cyst ("aspergilloma" or fungus ball) that ultimately disclosed a meniscus sign. Three others were malignant. One of these was metastatic from the kidney; the other two were bronchogenic carcinomas. The catastrophic result of prolonged observation of one of these is shown in Fig. 2. Equally reprehensible was the other case in which a therapeutic pneumothorax was induced after cavitation occurred and was maintained for over a year while the thick-walled cavity gradually grew larger. Such examples serve to illustrate the great hazard in utilizing

cavitation as an indication of benignity. In fact, out of 18 solitary nodules with cavitation analyzed by Rigler at least 11 proved to be malignant, thus forcing him to the conclusion that the presence of cavitation in a lesion showing no other evidence of an inflammatory process should be considered indicative of a malignant tumor.[35]

i. *Satellite nodules:* Although there has been little written on the subject, the presence of small satellite nodules in the roentgenogram provides reasonable assurance that a lesion is benign. Such nodules were radiographically demonstrable in 3 cases in this series, all being granulomas, one containing Coccidioides, another Histoplasma, and the other showing no organisms in specially stained tissue section. Many others, especially among the histoplasmomas, presented small subpleural satellite nodules at operation, but these were seldom well defined in the x-ray. Once again, however, there is no guarantee of benignity, a point emphasized by Overholt and his associates.[73]

*Thoracotomy.*—In the final analysis the one dependable diagnostic aid, in fact the only uniformly reliable one outside of autopsy, is thoracotomy. Fortunately, this carries as an added dividend the opportunity to excise the lesion which in most instances is the treatment of choice anyway. All patients in our series ultimately came to thoracotomy. This in itself has convinced us of the futility of elaborate preoperative investigations.

The types of operation utilized in our 215 cases are indicated in Table VII. In all cases the magnitude of the resection was dictated by a correlation of the patient's condition, the gross findings at operation, and the results of frozen-section tissue examination. In 8 cases, all of them unresectable carcinomas observed for more than one year prior to surgical consultation, the operative procedure was limited to exploration and biopsy. In all other cases the lesions were resectable, having been treated most commonly by a limited resection if benign, and either pneumonectomy or lobectomy if malignant. As will be pointed out in later discussion of bronchogenic carcinoma, we have come to regard lobectomy as a perfectly acceptable procedure in many of the peripheral carcinomas unassociated with gross lymph nodal involvement. One other aspect of Table VII deserves elucidation and that is the performance of eleven pneumonectomies for benign lesions. This simply reflects the fact that early in our experience we were less adept at distinguishing benign from malignant tumors and considered pneumonectomy to be the only adequate operation for bronchial carcinoma.

Our mortality rate with thoracotomy plus a limited resection (108 cases) has been nil. However, among those with lobectomies and pneumonectomies (107 patients), there have been five hospital deaths, four after pneumonectomy and one following lobectomy, the pathologic diagnosis in each case being bronchogenic carcinoma. Another patient with a large granuloma died at home suddenly and unexpectedly six weeks following pneumonectomy. He too has been included as an operative death bringing the total for the series to six (2.8 per cent).

TABLE VII. OPERATIONS AND OPERATIVE MORTALITY
215 SOLITARY PULMONARY NODULES

| LESION | TOTAL CASES | PNEUMONECTOMY | LOBECTOMY | SEGMENTAL RESECTION | WEDGE RESECTION | ENUCLEATION | EXPLORATION AND BIOPSY | DEATHS |
|---|---|---|---|---|---|---|---|---|
| Bronchogenic carcinoma | 79 | 39 | 30 | 1* | 1† | - | 8 | 4‡ |
| Bronchial adenoma | 9 | 4 | 2 | 2 | 1* | - | - | - |
| Primary sarcoma | 2 | 1 | — | 1* | — | - | - | 1§ |
| Lymphoblastoma | 1 | 1 | — | — | — | - | - | - |
| Metastatic tumor | 10 | 1 | 2 | 1 | 6 | - | - | - |
| Granuloma | 82 | 2 | 12 | 3 | 64 | 1 | - | 1‖ |
| Hamartoma | 9 | 1 | — | 3 | 3 | 2 | - | - |
| Mesothelioma | 6 | 1 | — | — | 4 | 1 | - | - |
| Chronic pneumonitis | 4 | 2 | — | 2 | — | - | - | - |
| Bronchial cyst | 3 | 1 | — | — | 2 | - | - | - |
| Bronchopulmonary sequestration | 3 | 1 | 2 | — | — | - | - | - |
| Neurofibroma | 2 | — | 1 | — | — | 1 | - | - |
| Chronic lung abscess | 2 | 1 | 1 | — | — | - | - | - |
| Lipoid granuloma | 1 | 1 | — | — | — | - | - | - |
| Lymph node | 1 | — | — | — | 1 | - | - | - |
| "Aspergilloma" | 1 | 1 | — | — | — | - | - | - |
| Total | 215 | 57 | 50 | 13 | 82 | 5 | 8 | 6 (2.8%) |

*Frozen section—benign.
†Frozen section—metastatic.
‡Three deaths following pneumonectomy; one after lobectomy.
§Died after pneumonectomy.
‖Patient did well postpneumonectomy, but died suddenly six weeks later.

The morbidity rate has been correspondingly low. Early in the series there were five postpneumonectomy bronchopleural fistulas with empyema. All eventually healed following pleural drainage and thoracoplasty. During the last eight years of this study there have been but two empyemas following pneumonectomy and both of them responded well to aspiration plus combined systemic and intrapleural antibiotic administration. There were 2 patients who, after wedge resection of supposedly nonspecific granulomas, developed tuberculous reactivation and required long-term chemotherapy plus completion of the lobectomy. Finally, one other case, following a wedge resection for a nonspecific granuloma, was complicated by a persistent bronchopleural fistula which responded to completion of the lobectomy and long-term antituberculous chemotherapy, the latter despite our failure ever to prove a tuberculous etiology. Except for these cases, all patients did well and were discharged from the hospital on an average of eight to ten days postoperatively.

The absence of any mortality from exploration and limited resection alone, the reasonably low mortality rate following more radical resection and the absence of any appreciable morbidity, except in cases of carcinoma and tuberculosis where it might be anticipated anyway, provides to our way of thinking convincing proof of the safety in exploring every patient with a solitary, noncalcified pulmonary nodule.

PATHOLOGIC ENTITIES

*Bronchial Carcinoma.*—Besides being the most important single entity included among the solitary pulmonary nodules, bronchial carcinoma rivals the granulomas as the most common. In our series there were 79 bronchial carcinomas (36.7 per cent) as compared with 82 granulomas (38.1 per cent), these two lesions together comprising 75 per cent of total nodules.

Breakdown by cell type is interesting (see Table II) although not differing significantly from accepted figures for peripherally situated carcinomas. Most frequent were the adenocarcinomas, numbering 36 in all, including 9 bronchiolar carcinomas. There were 34 squamous carcinomas. The other 9 were undifferentiated carcinomas. This is decidedly different, of course, from bronchial carcinomas, in general only about 13 per cent of which are adenocarcinomas,[74] but quite in keeping with the work of Walter and Pryce who have shown that primary adenocarcinomas of the lung arise predominantly if not invariably in the periphery.[75] Insofar as survivorship is concerned, the end results are somewhat surprising, for they suggest, though admittedly in figures far short of statistical significance, that the adenocarcinomas and undifferentiated carcinomas have as favorable a prognosis as the squamous variety. Thus, the survivors include 15 patients with squamous carcinoma (44 per cent), 17 with adenocarcinoma (47 per cent), and 4 with undifferentiated carcinoma (44 per cent). We attributed this at first to chance, but note that Belcher recently concluded after an elaborate study that patients with adenocarcinoma amenable to lobectomy have a better prognosis than those with squamous carcinoma so situated as to be suitable for lobectomy.[76] Similarly, undifferentiated carcinomas appeared to him to have not nearly as bad a prognosis when lobectomy was possible as they did when the tumor was more extensive, even to the point that their 2-year survival rate closely approximated that for squamous carcinoma (43 per cent versus 40 per cent).[76]

Where our results were worst was among the bronchiolar (alveolar cell) carcinomas. In our experience these have carried a poor prognosis. All but 3 of our 9 patients with bronchiolar carcinoma have now died or are in the process of dying and 2 of the remaining 3 were resected much too recently (two and four months, respectively) for anyone to guess their ultimate fate. We would agree therefore with those from the Mayo Clinic whose survival rates after resection of these tumors parallel our own.[77] Despite the fact that the bronchiolar carcinomas in our series were mostly small asymptomatic lesions unaccompanied by nodal involvement and upon microscopic examination were better differentiated than the average adenocarcinoma, we have yet to encounter what we would label "favorable bronchiolar carcinoma" as it has been called by Overholt and his associates.[78]

While our over-all results in the surgical management of the malignant solitary nodule are far from ideal, they manifest little of the pessimistic overtones generally associated with bronchial carcinoma. Out of 79 patients in this series having bronchial carcinoma, 34 are still alive in seeming good health, while an additional 2 cases can be justifiably considered cured by

surgery although having subsequently succumbed to other causes. These latter 2 patients were operated upon in their sixties and died in their seventies (one eight years and the other five years, postoperatively) without showing any demonstrable recurrence either clinically or at autopsy. Another patient whose tumor was a squamous carcinoma lived for eleven years following pneumonectomy but died with spinal metastasis and is not included in the group of survivors. As suggested by two independent groups in 1948,[79, 80] there is a reasonably close correlation between the 2- and 5-year survival rates, and it is on this basis that our own survival rates have been calculated. There are then 36 patients (45.6 per cent), who can be regarded as potential "cures," with 17 patients being 3-year survivors, 10 more being 2-year survivors and the remaining 9 patients being less than two years postoperative. This figure is disappointing on the surface, but becomes a good deal more optimistic considering that, of the 43 patients who did not survive, 28 had been observed by their physician for periods in excess of six months and 20 of these had actually had the growth of their nodules checked periodically for over a year.

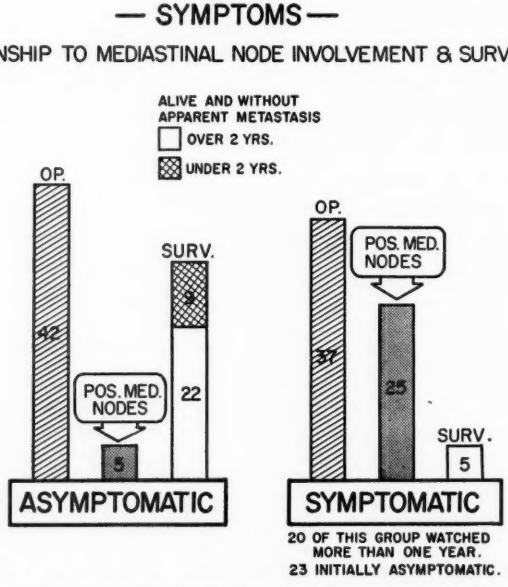



Fig. 15.—Illustration of the prognostic significance of symptomatology both upon mediastinal lymph node involvement and ultimate survivorship.

In other words, many were robbed of a chance for cure long before being referred for surgical consultation.

The presence of symptoms, or preferably their absence, had an impressive influence upon survivorship. Out of the 79 patients with bronchial carcinoma, 65 were asymptomatic when the radiographic density was first detected. As a reflection of the long periods of observation forced upon so many of these

patients, an additional 23 developed symptoms before coming to operation. Thus, at the time of thoracotomy 37 patients had symptoms whereas 42 had none. These are shown in Fig. 15. Of the 42 who were symptom free 31 (74 per cent) are surviving in apparent good health without evidence of recurrent carcinoma. Admittedly 9 of the survivors are less than two years postoperative but even discounting these there are still 2 survivors out of every 3 patients with solitary circumscribed bronchial carcinomas operated upon in the asymptomatic phase. By contrast, among the 37 patients operated upon after the appearance of symptoms only 5 survive (13 per cent).

Moreover, there has been a rather clear-cut relationship between the existence of symptoms and mediastinal lymph nodal involvement. Whereas only 5 (12 per cent) of those without symptoms showed microscopic evidence of mediastinal lymph node involvement, 25 (67.5 per cent) of the symptomatic group exhibited metastatic tumor in one or more mediastinal lymph nodes and 8 of these were unresectable. Conversely, the asymptomatic lesions were uniformly resectable. The relationship of symptomatology to both mediastinal node involvement and survivorship is illustrated in Fig. 15. These findings are in general agreement with other reports on asymptomatic bronchial carcinoma,[73, 81] at least in the broad sense that the asymptomatic lesion has a higher rate of resectability and a potentially higher rate of curability

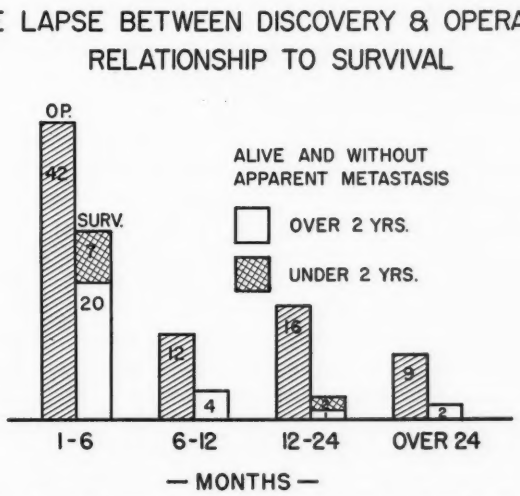



Fig. 16.—Illustration of the influence upon survivorship of the time lapse between detection and resection of the nodule.

than symptomatic carcinoma of the lung. In our experience this difference has been impressive enough to constitute a telling argument in support of routine and survey chest roentgenograms of asymptomatic patients.

An analysis of the time lapse between discovery of the lesion and operation and its relationship to survival is shown in Fig. 16. Forty-two of the 79 patients with bronchial carcinomas were operated upon within six months

after roentgenologic detection of the lesion. Twenty-seven of this group (64 per cent) survive in apparent good health without evidence of metastasis. When operation was delayed six months to a year only 4 (33 per cent) out of 12 patients survived and when delayed over one year 5 (20 per cent) of 25 survived. Interestingly enough, there were 2 patients who are alive and well three and six years after resection despite having been observed preoperatively by their physicians for two and three years, respectively. Still another patient was followed for three years before being referred for surgery. He was alive and well when last heard from four years postoperatively, but he was subsequently lost to follow-up and has not been counted as a survivor. Nevertheless, these 3 cases demonstrate the indolence and relatively low biologic activity of an occasional carcinoma of the lung. More often than not the opposite tends to be true, however; hence the need for prompt excision seems inescapable; the sooner the resection the better the chance for cure. Our experience leads us to believe that the small solitary circumscribed asymptomatic bronchial carcinoma recently picked up in a fortuitous chest roentgenogram, an admittedly small segment of all bronchial cancer unfortunately, has a good chance for complete eradication if operated upon promptly. Thirty-two of our patients fall into this category and 24 (75 per cent) survive in apparent good health. Out of this group there were 14 operated upon over five years ago and 11 (78 per cent) are alive and well today. While the number of cases quoted is much too small to assume statistical significance, it suggests that the 5-year survival rate in bronchial carcinoma so situated and so handled approaches 75 per cent.

Finally, it is highly significant, we feel, that the extent of surgery (pneumonectomy versus lobectomy) does not appear to have any significant effect upon the ultimate survival of certain cases and we now regard lobectomy as a perfectly sound and adequate cancer operation in properly selected cases, the chief requirements being a well-circumscribed lesion, peripherally situated and free of gross lymph nodal involvement. As far back as 1934, the Mount Sinai group[82] pointed out the singular behavior of these tumors and made reference to their suitability for lobectomy, but like many another concept too far ahead of its time this proposal met with much undeserved abuse each time it was reintroduced.[79, 83] Subsequent comparisons of survival rates for lobectomy as opposed to pneumonectomy[76, 84-89] clearly vindicate their contention, however, as does an analysis of our own cases.

The surgical procedures performed on the 79 patients with bronchial carcinoma consisted of pneumonectomy 39 times, lobectomy 30 times, biopsy 8 times, and limited resections twice, the latter having been prompted by erroneous frozen-section diagnoses (Table VII). Of the 36 survivors, 20 had had pneumonectomies and 16 had had lobectomies, in other words about one half of the original pneumonectomies and one half of the lobectomies survive. Among those treated by pneumonectomy, 12 are living and well more than five years postoperatively, 5 between two and five years postoperatively, and 3 less than two years postoperatively. Among the lobectomies 5 are 5-year

survivals, 5 more are 2-year survivals, and 6 are not yet two years postoperative. To us the feature of greatest significance is the fact that those who died of recurrent carcinoma following lobectomy died not of local recurrence but from generalized metastases, most frequently cerebral. Thus the trend in our management of these patients has changed from routine pneumonectomy to lobectomy whenever feasible. When no gross evidence of lymph node involvement has been noted and the lesion was confined to the periphery of a lobe, our results with lobectomy have been as good as those with pneumonectomy.

On the other hand, we do not mean to imply that lobectomy is a satisfactory substitute for pneumonectomy in less favorable situations. When the tumor encroaches upon the hilus or when enlarged hilar or mediastinal lymph nodes are present, we consider pneumonectomy to be the treatment of choice. Nevertheless, as pointed out by Boyd and his co-workers,[86] a fairly radical lobectomy can be performed, especially in upper lobectomy, and it is thought-provoking to find Belcher[76] stating that further elucidation of the lymphatic drainage of the lung "may show that it is as irrational to recommend pneumonectomy for an upper-lobe tumour as it would be to remove the entire colon for carcinoma of the sigmoid." Regardless of additional refinements in technique that may eventually appear, it seems clear to us at this point that lobectomy very definitely has a place in the management of the primary malignant solitary nodule, carrying with it a considerable reduction in operative mortality and preservation of pulmonary function without significantly reducing the chance for long-term survival.

*Bronchial Adenoma.*—As far as bronchial adenomas are concerned only two features require comment here. First is the question of their malignancy; second, their not infrequent though seldom appreciated tendency to arise peripherally.

That they are all potentially malignant is well known. To be convinced of this one has but to witness the lymphatic and sometimes more extensive metastases associated with a perfectly benign-looking tumor, or run into a recurrence following local excision of an apparently benign lesion or encounter frank carcinomatous transformation in an otherwise benign adenoma. Considering how difficult it may be to prove the origin of a carcinoma from an adenoma, this last possibility may occur more commonly than we think. For these reasons we personally regard all bronchial adenomas, be they carcinoids or cylindromas, as low-grade adenocarcinomas having an exceedingly favorable outlook if excised early but a guarded and oftentimes fatal prognosis if neglected indefinitely. Since no one would dispute the need for their excision, it seems justifiable to classify them as malignant lesions. However, we have not gone so far as to lump the adenomas in with the carcinomas for fear someone might infer that the high incidence of bronchial carcinoma among our solitary nodules might be due to artificial padding. Actually the opposite is true, because several lesions originally thought to be bronchial carcinomas were reclassified as adenomas after reviewing the histologic sections as a part of this study.

The other point, that is, the chance of their assuming a peripheral position also deserves emphasis, for in the popular mind the typical adenoma is a central obstructive tumor not a peripheral solitary nodule. Nevertheless, about 10 per cent will arise far enough peripherally to present the radiographic appearance of a solitary nodule.[90] Nine nodules in our series turned out to be bronchial adenomas, an incidence of 4 per cent which is somewhat higher than that in most series but only one half that reported from the Mayo Clinic.[11]

Surprisingly, 5 of the adenomas in our series occurred in men and only 4 in women. There were 6 carcinoids, 2 cylindromas, and one well-differentiated mucous gland adenoma.[91] There was lymph node involvement in but one case, and all 9 patients remain alive and well for periods ranging from two to eleven years.

*Rare Primary Pulmonary Malignancy.*—There is little need to expound upon the many malignant tumors that arise occasionally in the lung and still less commonly present as a solitary nodule. Representative examples such as a fibrosarcoma, a leiomyosarcoma, and a lymphoblastoma are included in our series. The subject of bronchopulmonary sarcomas has recently been comprehensively covered with special attention to their rarity, peripheral location, predominance in middle-aged persons, difficulties in pathologic differentiation, and amenability to surgical excision.[92] A number of entities both malignant, such as, oat-cell and pleomorphic-cell carcinoma, and benign, for example, postinflammatory pseudotumors,[93] are apt to be mistaken for pulmonary sarcomas thus emphasizing the need for the greatest of care in microscopic interpretation. The one fibrosarcomatous nodule in our series occurred in a 51-year-old man. The lesion had enlarged slowly over a 3-year period of observation, yet there was no evidence of nodal involvement at pneumonectomy. To our dismay he died forty-eight hours postoperatively of undetermined cause. The patient with a leiomyosarcoma was a 52-year-old man who remains in good health five years postoperatively despite a very limited resection imposed by the frozen-section tissue diagnosis of a benign lesion. The third patient was a 39-year-old woman who had a pneumonectomy for a lesion diagnosed as a lymphoblastoma. There was no lymphatic metastasis. X-ray therapy was withheld pending the appearance of metastases which to our amazement have not yet appeared. She remains in good health eleven and one-half years later and represents as far as we can determine[94] the longest surviving case of resected primary pulmonary lymphoma on record.

*Metastatic Malignancy.*—Ten of the solitary nodules in our series proved to be metastatic to the lung. All but 2 of the patients had had prior cancer surgery anywhere from one to twelve years earlier. In each of these cases, the possibility that the pulmonary nodule represented a solitary metastasis was seriously considered, yet on the other hand there were 3 more patients who had had a primary extrapulmonary carcinoma resected previously, all 3 of whom turned out to have a separate primary carcinoma of the lung. This then is the chief reason for advising prompt thoracotomy in a patient with a solitary pul-

monary nodule and a history of a previously excised malignancy. Admittedly, the likelihood of finding a metastatic nodule stands high, but not high enough to invalidate the possibility of a primary bronchial carcinoma, especially when the interval between operations is relatively long.

The merits of resecting metastatic pulmonary nodules are dubious at best. When there is but one demonstrable metastasis, however, its excision may be worth while, achieving definite prolongation of life in some instances and less frequently a long-term survivor, the classic example being a patient with a hypernephroma whose case was reported by Barney and Churchill[95] in 1939, with a 9-year follow-up after resection of a solitary metastatic deposit in the lung. The essential requirements, of course, are a reasonable assurance that the primary malignancy has been controlled and the inability to demonstrate more than one site of metastasis. Ideally, an adequate interval of time, preferably three years or so, should have elapsed between operations for the primary and secondary lesions. But the logic in delaying the second operation to see whether additional metastases shall appear is apt to be nullified by the fact that the nodule may be primary rather than metastatic. Moreover, in a superb analysis by Seiler and his associates,[96] it could only be concluded that contrary to expectations the patients with a long hiatus between the two operations did no better than the group as a whole.

Needless to say, the cell type and organ of origin are other factors influencing the chance for cure, although these too are in no sense reliable. Generally speaking the outlook for those due to carcinoma of the skin, cervix, colon, kidney, ovary, and breast is probably better than for those from other locations.[97] Likewise the prognosis is possibly more favorable for metastatic sarcoma than for metastatic carcinoma.[98, 99] When all is said and done, however, the chance for complete eradication is extremely remote. Characteristically, once a secondary tumor appears, widespread metastases are usually soon to follow. This is exemplified by one of our patients who, after nephrectomy for hypernephroma, survived twelve years before a metastatic nodule appeared in the lung, only to have signs of cerebral metastasis arise within one month after pulmonary resection.

Of the other 9 patients, 2 had no previous history of carcinoma and the primary sites were detected only after microscopic recognition of the metastatic nature of the pulmonary lesion. Neither of these patients survived more than two years. This particular situation, operation upon the metastasis prior to the primary malignancy, was so rarely encountered in our series that there would seem to be little justification for an elaborate search for a primary extrapulmonary tumor in the preoperative study of the indeterminate solitary pulmonary nodule. Without some clue to a primary elsewhere the direct approach to the pulmonary lesion would seem more logical, less time consuming and perhaps less expensive in the long run.

In our series of metastatic pulmonary tumors the survivorship has been rather dismal although not entirely discouraging. Only 4 patients are still alive. Two (colon and breast) have recurrent carcinoma twenty-one and

fourteen months following thoracotomy. The other 2 (breast and osteogenic sarcoma) are living in apparent good health without evidence of further metastasis fifty-eight and forty-three months, respectively, after resection of a solitary pulmonary metastasis.

*Granuloma.*—In practically every series of solitary pulmonary nodules the most common single entity has been the granuloma. Thirty-eight per cent of our series were granulomas as were 41.6 per cent of nodules reported in other series (see Table I). They account for by far the bulk of the benign nodules. Traditionally these lesions have been called "tuberculomas," an etiological assumption usually based on nothing more than their gross appearance. Even when soft or cavitary, such granulomatous foci more often than not are negative for acid-fast bacilli both culturally and histologically and when the nodule is old and laminated, and especially when partly calcified, the bacteriologic yield is almost negligible. Even then, if the only positive skin sensitivity test is the tuberculin, a presumptive diagnosis of a tuberculoma might be justified, but for one to incriminate a tuberculous origin in the face of a negative skin test is a precarious position indeed. Hence it should take only one large series like Mahon and Forsee's,[43] in which 30 per cent of the "tuberculomas" were accompanied by a negative tuberculin skin test, to convince one that another organism might be responsible for some of these infections.

TABLE VIII. 82 GRANULOMAS (RADIOGRAPHICALLY NONCALCIFIED)

| | | |
|---|---|---|
| Studied by special stains | | 71 |
| Tuberculoma | 12 (17%) | |
| Histoplasmoma | 39 (55%) | |
| Histoplasmic lymph node | 1 | |
| Coccidioma | 5 (7%) | |
| Diagnosed | 57 (80%) | |
| Nonspecific | 14 (20%) | |
| (possible Histoplasma, 2; possible Cryptococcus, 2) | | |
| Not studied | | 11 |
| (tissue not available) | | |
| | Total | 82 |

Actually the idea that fungi might produce lesions indistinguishable from the so-called tuberculoma is by no means new. As far back as 1915, Coccidioides were demonstrated in such a nodule,[100] but it was not until 1939 that Cox and Smith[101] called special attention to the "arrested pulmonary coccidioidal granuloma." Since then the coccidioma has been thoroughly restudied by various investigators[102-106] who have established both its prevalence and its pathologic significance.

In contrast to the coccidioidal residual in which sporangia can almost always be identified if a persistent microscopic search is made of hematoxylin and eosin-stained sections, proof of the histoplasmic etiology of comparable lesions has been greatly delayed by the infinitely greater difficulty in demonstrating Histoplasma in quiescent, presumably inactive foci. Only by the recent development of more sensitive tissue stains has identification of the organism been possible in such cases. Using the periodic acid-Schiff (PAS)

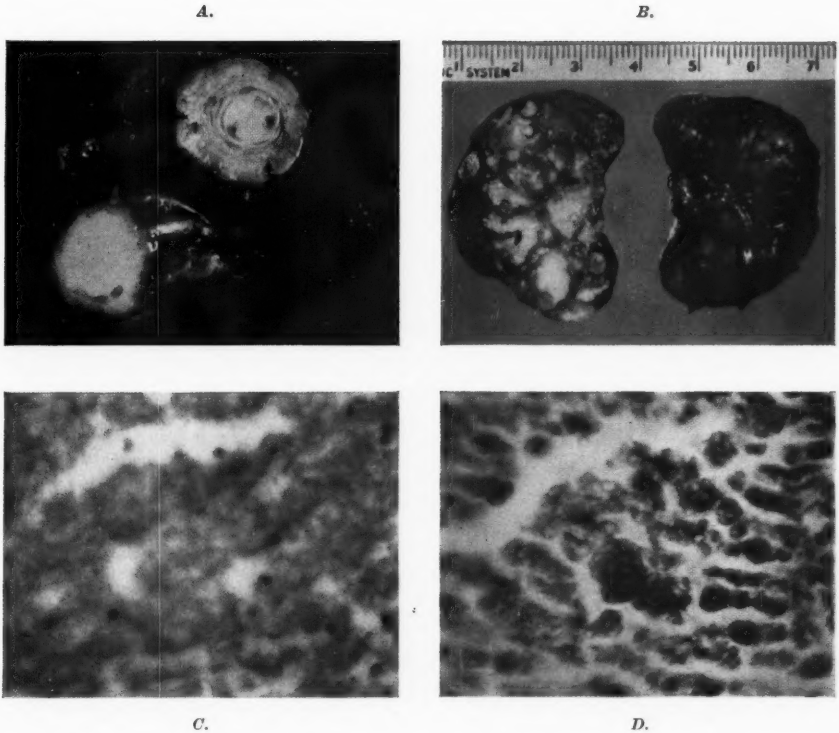



Fig. 17.—The residual histoplasmic focus.

*A*, Transected specimen of a typical histoplasmoma showing the characteristic pleural plaque, concentric laminations, and necrotic center.

*B*, Transected bronchial lymph node that presented as a pulmonary nodule (see Fig. 7) and appeared grossly granulomatous. Special stains revealed myriads of Histoplasma.

*C*, Hematoxylin and eosin-stained tissue section from a so-called "tuberculoma" showing nothing but coagulation necrosis.

*D*, The very next section, stained by the periodic acid-Schiff method and centered on the same microscopic field seen in *C*, discloses an impressive number of typical Histoplasma.

stain, Puckett[107, 108] was able to identify Histoplasma in 22 resected granulomas all of which fit the gross and microscopic picture of healed tuberculomas. This highly significant finding has been adequately confirmed by Zimmerman,[109, 110] Binford,[111] one of us,[112] and in a subsequent report by Puckett,[113] but to date has gained little acceptance by the majority of pathologists, most of whom retain the erroneous notion that routine staining methods are quite adequate for the demonstration of fungi. We readily concede that in active lesions, particularly in the presence of progressive disease, the ordinary hematoxylin and eosin stain is quite satisfactory for diagnosing the deep mycoses. However, in mild, healing, or "burnt out" infections fungi are apt to stain poorly if at all by this method[114] and require a special stain such as the PAS, Gridley,[115] or methenamine silver nitrate[116] for their demonstration. This point can be conclusively proved by a comparison of identical tissue sections stained by different techniques (Fig. 17). In the hematoxylin and eosin-stained section taken through the central necrotic zone of a pulmonary granuloma, no organisms are visible. In striking contrast the very next section from the same paraffin block discloses a vast number of typical Histoplasma when stained by the PAS method. Inasmuch as other mycoses such as cryptococcosis[12, 13, 117] and on rare occasions blastomycosis[106, 118, 119] and even geotrichosis[106] and mucormycosis[120] have also been incriminated as a cause of a "tuberculoma," we were extremely anxious to investigate this aspect of our granulomas.

An attempt was made to obtain the paraffin-tissue blocks of all granulomas included in this series. This was possible in 71 cases. Multiple sections were then recut and at least nine stained slides, three with the Ziehl-Neelsen stain, three with the PAS stain, and three with the Gridley stain were meticulously re-examined. Histoplasma were clearly seen in 40 cases, one being a lymph node; Coccidioides in 5 cases; and acid-fast bacilli in 9. However, in three additional instances, the tuberculous nature of the infection was proved by recovery of tubercle bacilli in culture, once from the resected specimen and twice from the sputum when the process recurred postoperatively in the operated lobe (Fig. 18). Thus, 12 granulomas were true tuberculomas. In 4 other cases forms suspicious but not diagnostic of Histoplasma (twice) and Cryptococci (twice) were seen, but because of insufficient evidence these, along with 10 other cases in which no organisms were seen, are classed as nonspecific granulomas. As shown in Table VIII a positive diagnosis was possible in 80 per cent of the cases studied. The largest percentage of these, 55 per cent of the total number studied, were histoplasmomas, while another was a histoplasmic lymph node. Seventeen per cent of those studied proved to be tuberculomas and 7 per cent were coccidiomas. Another six resected specimens that are not included in our series of solitary nodules because they contained calcium were also shown to be histoplasmomas (see Table V). It becomes quite obvious therefore that the majority of pulmonary granulomas, instead of being tuberculous, are actually mycotic in origin. Additional study is indicated to determine the etiology of the as yet undiagnosed granulomas, some of which are undoubtedly silicotic,[48] while others, such as 2 reported cases caused by brucella,[63] must result from bacteria other than the tubercle bacillus.

The prognostic significance of these granulomas is difficult to assess. A number of publications suggest that the tuberculomas warrant excision because of the constant threat of reactivation. Barring the cavitary and the soft exudative lesions, we are not so sure this is necessarily true; hence our willingness to observe the partially calcified pulmonary nodule. In a paper frequently quoted as an argument in favor of resection, Mitchell[121] concluded that with prolonged observation of a solitary dense tuberculous pulmonary focus there was about one chance in four of progression of the disease when untreated by resection or chemotherapy, but severe progression was rare and none proved fatal. Moyes[122] demonstrated an even higher rate of instability than Mitchell but showed a better ultimate prognosis and the only death in his series resulted from a bronchopleural fistula following resection. Moreover, as Macleod and Smith point out, "We must be chary of too ready acceptance that the round focus is responsible for the spread of disease. All

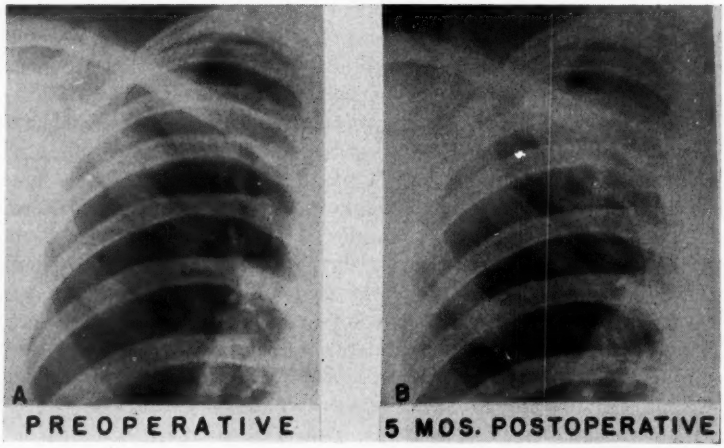



Fig. 18.—*A*, Preoperative x-ray of a patient with a solitary nodule in the right first anterior interspace. Tuberculin and histoplasmin skin tests were both positive. Sputum and gastric washings were negative for acid-fast bacilli. Neither AFB nor fungi could be demonstrated in the wedge-resected granuloma. No chemotherapy was given. *B*, Roentgenogram taken five months postoperatively reveals a cavitary lesion at the operative site at which time sputum was positive for AFB. Patient required chemotherapy and completion of the lobectomy.

This and another case like it convince us of the necessity of treating every nonspecific granuloma with antituberculous chemotherapy whenever the tuberculin skin test is positive. If, on the other hand, the tuberculin test is negative or if fungi can be demonstrated in the necrotic center, additional treatment would not seem to be necessary.

patients with tuberculous disease are liable to break down. The round and apparently solitary focus is so frequently accompanied by other tuberculous foci in the lung that these radiologically invisible lesions may well be the source of bacilli."[123] In what is undoubtedly the most painstaking study yet conducted on this problem, Hillerdal[124] was impressed by the favorable long-term prognosis among patients with untreated tuberculomas. Bronchogenic spread was uncommon. When it did occur, the disease in every instance was easily controlled by chemotherapy and involved no great danger to the patient. Two factors account for the frequency with which such nodules need to be

excised, however, these being the inability to rule out malignancy in the recently discovered tuberculoma and the possibility that it is a blocked cavity when serial x-rays show it to be the residual of more extensive, previously treated disease. Even so, whenever calcification can be seen within the nodule, trouble from either of these two possibilities is so remote that we regard medical observation as the logical course to follow.

In the case of the solitary mycotic foci we are still more certain of the advisability of leaving them alone, provided of course that malignancy can be ruled out. The occurrence of cavitation within the solid coccidioidal residual is not common and is even less likely to occur in the histoplasmoma. Dissemination from such a nodule is almost unheard of, although alluded to on at least one occasion.[124] Perhaps the best reason for not expecting any trouble from these focalized fungal infections is the questionable viability of the organisms as manifested by the great difficulty in culturing anything from the specimen. Although one writer infers that their recovery can be anticipated,[125] our own experience bears out that of Puckett,[107] in that only once have we been able to culture *H. capsulatum* from one of these histoplasmonas, and never have we had a recurrence regardless of how limited a resection was done. The fact that these healed mycotic foci are so innocuous as well as the fact that they represent a substantial portion of the partially calcified nodules seems to us to provide additional justification for a program of observation in the case of the solitary nodule containing unequivocal radiographic evidence of calcification.

When neither acid-fast bacilli nor fungi can be demonstrated in the specimen, a dangerous sense of security may develop. In such a situation we twice permitted an avoidable recurrence by failing to have proper respect for the possibility of tuberculosis (see Fig. 18). Both of these patients had limited resections; both had positive tuberculin and histoplasmin skin tests; neither received antimicrobial chemotherapy following operation and both developed recurrence in the remainder of the involved lobe. Although each of these patients is recovering after prolonged chemotherapy plus completion of the lobectomy, the use of prophylactic antituberculous chemotherapy postoperatively would in all likelihood have obviated a second operation. As a result of this experience we are convinced that, provided the tuberculin skin test is positive, the granuloma in which neither acid-fast bacilli nor fungi can be demonstrated deserves at least six months' antituberculous drug therapy as a precautionary measure.

*Hamartoma.*—Hamartomas are generally regarded as rare pulmonary tumors, when in reality they are probably not too uncommon. In the Mayo Clinic series,[11] for example, hamartomas were as common as bronchial carcinomas, comprising 16 per cent of all their solitary nodules. We have encountered only 9 in our series and 2 of these were resected from the same patient in operations performed five years apart.

Regarding hamartomas, easily the outstanding question at the moment concerns the widely accepted view that these tumors are always benign. Simon and Ballon[126] are often referred to as the only ones to report a malig-

nant hamartoma, and in that case the diagnosis rested solely on marked cellular proliferation and capsular invasion within the nodule. Recently there appeared a case report of a pulmonary osteochondrosarcoma that probably arose in a partly calcified hamartoma[127] and another report of a malignant hamartoma was published abroad.[128] In answer to our question about malignancy arising in a partly calcified nodule, 2 malignant hamartomas were cited (see Table VI), the one by Ballon referred to above,[127] and another by Effler, as yet unreported. We have also learned from Klepser[129] that he too has excised a malignant hamartoma containing cartilage but no calcium. There seems to be little doubt therefore that malignancy can arise in the hamartoma, although it is apparently seldom that it does so.

*Pleural Mesothelioma.*—The solitary fibrous type of pleural mesothelioma commonly creates the radiographic impression of a pulmonary nodule although in truth it is extrapulmonary. One of the major problems in categorizing the various solitary pulmonary nodules is the difficulty in differentiating localized pleural mesotheliomas from fibromas, fibrosarcomas, neurofibromas, and neurofibrosarcomas, for any of which they are apt to be mistaken. Clubbing of the digits and arthralgia are frequent accompaniments of this tumor but were noted in none of the mesotheliomas in this series, due perhaps to the fact that the large mesotheliomas with which arthropathy is more apt to be associated[130] are excluded from this study. Even when present such signs provide no help in ruling out bronchial carcinoma. Moreover, regardless of their benignity, mesotheliomas warrant excision on their own merits owing to the tremendous size they may ultimately achieve.

*Unresolved Pneumonitis and Abscess.*—On a few occasions chronic inflammatory processes will take the shape of a fairly well-defined pulmonary nodule. Since they are likely to be accompanied by symptoms such as hemoptysis (see Table IV) and because the margin of this kind of nodule is apt to be a little fuzzy, the resemblance to a carcinoma may be more striking than will the average nodule.

*Bronchogenic Cysts.*—Those bronchogenic cysts unassociated with a bronchial communication can distend with mucus or pus and thus assume the appearance of a pulmonary nodule. It was of interest to us that out of 6 such cysts that we have encountered, closer scrutiny showed 3 to have an anomalous blood supply from the aorta, thus throwing them into the category of intralobar bronchopulmonary sequestration (see Fig. 7).

*Rare Primary Benign Pulmonary Lesions.*—The benign pulmonary lesions that in rare instances will present as a solitary pulmonary nodule are almost too numerous to mention. They include an occasional neurofibroma, fibroma, hemangioma, arteriovenous fistula, leiomyoma, lipoma, and even thymoma. Once again, histologic differentiation may be quite difficult, as witness a recent report on sclerosing hemangiomas of the lung in which the question is raised as to whether some lesions heretofore classified as xanthomas, granulomas, or postinflammatory tumors may not in reality represent sclerosing hemangiomas.[131] There is little doubt that there is room for improvement in our pathologic inter-

pretation of many of these nodules, as is illustrated by one of our earlier nodules that had been originally interpreted by the pathologist as an infarct and was so labeled until recently when the application of special stains showed it to be a histoplasmoma.

Almost without exception we have found something interesting and instructive in each of the solitary pulmonary nodules in this series.

## SUMMARY

This report represents the culmination of a study initiated in 1946 concerning the significance of the solitary pulmonary nodule. Our own series of 215 personally resected, noncalcified pulmonary nodules correlates well with the literature in illustrating both the strong malignant propensity of these nodules as well as the improbability of distinguishing the benign and the malignant lesion by any means short of thoracotomy.

Thus in our series, 47 per cent were malignant, 37 per cent being bronchial carcinomas. Clinical, laboratory, and roentgenologic data have been elaborately analyzed without finding any sign reliable enough to justify medical observation, unless it be calcification within the nodule. After polling the members of The American Association for Thoracic Surgery on this highly controversial issue, namely, the reliability of calcification as an indication of benignity, we are convinced that minimal calcification within a solitary pulmonary nodule, especially when no more than a fleck or two, is unjustifiable grounds for assuming it to be benign. There remain certain patterns of calcification that render the possibility of malignancy so slim, however, that further observation seems warranted. These include those nodules with a large central calcific core and diffuse calcific stippling, those with an inner ring or outer rim of calcium and, of course, those that are completely calcified.

In this survey the two groups deserving the greatest attention were the bronchial carcinomas and the granulomas which together comprise 75 per cent of total nodules. Our primary concerns have been the prognosis of the primary carcinomatous nodules and the etiology of the granulomas.

In determining survivorship of those with bronchial carcinoma, cell type appeared to have far less influence than did either the presence of symptoms or time lapse between radiographic discovery of the lesion and operation. Our findings indicate that the small solitary circumscribed asymptomatic bronchial carcinoma recently detected in a fortuitous chest x-ray has a 75 per cent chance of surviving five years if operated upon promptly. Lobectomy appears to be an adequate cancer operation in properly selected cases.

Early in this study, all of the solitary granulomas, because of their gross appearance if nothing else, were presumed to be "tuberculomas." Re-examination of the tissue blocks in these cases by special staining techniques has been most revealing. Fifty-five per cent of the granulomas studied contained Histoplasma and 7 per cent, Coccidioides, in contrast to but 17 per cent in which a tuberculous etiology could be established. The implications of these findings have been discussed in detail as have the various other types of solitary pulmonary nodules.

We can only conclude that every solitary, noncalcified pulmonary nodule demands thoracotomy, that for those with bronchial carcinoma the absence of symptoms and promptness of surgery are apt to determine the chance for cure, and that careful histologic study of the pulmonary granulomas will reveal the majority to be of fungal rather than tuberculous origin.

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## DISCUSSION

DR. DONALD L. PAULSON, Dallas, Texas.—I rise only to present our figures for the survival rates on patients who have had pulmonary nodules due to bronchogenic carcinoma.

(slide) This illustrates the distribution of tumors in 180 pulmonary nodules which Dr. Shaw and I have seen in the last ten years; there were 88 tumors and some 62 of those were due to bronchogenic carcinoma, an incidence of 34 per cent.

(slide) If we are to discuss the indications for removal with a medical man and insist upon removal of most indeterminate pulmonary nodules, it is important that we be able to quote our statistics as to survival rates. This slide deals with 24 pulmonary nodules due to bronchogenic carcinoma which are asymptomatic, and reveals a 75 per cent survival rate for two years or more after resection.

(slide) This deals with 41 symptomatic lesions, in contrast to the first slide, and we see the survival rate drop from 75 to 38 per cent for a period of two years or more after resection for those nodules associated with symptoms.

(slide) This is a combination of the two groups; in the entire group, whether or not the nodule was associated with symptoms, the survival rate is 50 per cent for two years or more after resection. There were no surgical mortalities. Six of 14 patients have survived five years or more after resection.

DR. ADRIAN LAMBERT, New York, N. Y.—This is an extremely important study and it is especially timely to call attention again to the importance of exploring these peripheral solitary nodules for the possibility of carcinoma of the lung. I would like to congratulate Dr. Davis on his work in this respect.

I should like to discuss briefly the factors influencing survival rate in these solitary pulmonary bronchogenic carcinomas. There are two factors that determine the survival rate in these tumors. The first is whether they are blood-borne in their metastasis, and the second is whether they spread via the lymphatics. If blood-borne metastasis has already occurred at the time of exploration, I do not think that anything the surgeon does is going to influence the survival rate. On the other hand, if extension occurs via the lymphatics, I think the determining factor is whether the involved lymphatics are going to be removed. For some time I have emphasized the importance of radical mediastinal lymph node resection for carcinoma of the lung. It is difficult at present to evaluate results of resection mainly for one reason. This is, that at the time of exploration these nodes are not catalogued and are not identified for the pathologist, so that when one evaluates the survival rate he may say such and such a number of nodes was involved, and such a group was not. In resection for mediastinal involvement, I think one should remove the right and left bronchial nodes, the carinal nodes, and, by and large, the paratracheal nodes on each side, and send them to the pathologist to be identified as such, so that when the patient comes back you will be able to evaluate the patient's survival with the extent of mediastinal involvement. In this respect, I should like to call attention to one other fact; that these lymphatic chains when blocked with tumor cells, will result in a flow of tumor cells to the other side in reverse direction, either to the upper lobe from the lower, or the lower lobe from the upper lobe, which is not usually mentioned in the description of lymphatic drainage by Poirer and Charpy and other authors.

I want to again thank Dr. Davis for his fine presentation.

DR. PEABODY (Closing).—I wish to thank the discussants and at the same time express our regrets that some of those who answered our questionnaire did not come forward to present examples of partially calcified solitary nodules that turned out to be

malignant. So far as we personally are concerned, there is adequate justification for the conservative management of the partially calcified nodule, provided of course the calcification consists of more than a mere fleck or two. Granting that 150 odd malignant lesions containing calcium were reported by members of the Association, a careful analysis of these reports showed that the majority were minimally calcified, and only a few presented extensive calcification. In other words, we tend to agree with Duane Carr, who replied in this fashion, "Recognizing the fact that calcium does not absolutely rule out malignancy, its presence within a malignant solitary nodule is so rare that the chance of its being benign is better than the probability of cure by resection if malignant." One thing that was not mentioned; we would certainly like the patient to have a positive skin test for one of the three major granulomatous diseases before agreeing to pursue a nonoperative plan of management. At the other extreme, we are thoroughly convinced of the danger in watching the minimally calcified nodule. Observation of such lesions was almost unanimously condemned by those answering our questionnaire, a point that needs to be emphasized to the internist.

Having expressed ourselves so emphatically on a subject still far from settled, it is our hope that those who feel differently will report their experiences for, as we see it, this entire issue is the most important question confronting the chest man today.

One of the more interesting aspects of the problem is the matter of the mycoses, several features of which deserve clarification or re-emphasis. For instance, Dr. Davis made mention of the fact that the West Coast does not have a corner on the coccidioidal market. To be completely honest about it, I must add that all our patients with coccidiomas gave a history of having been in the endemic zones, although in some instances it was for only a very brief period of time. By the same token, however, one does not have to visit the Mississippi Valley to contract histoplasmosis which, next to carcinoma of the lung, is probably one of the more common specific diseases we see in the District of Columbia. This includes, of course, histoplasmosis in an exceedingly broad radiographic spectrum.

(slide) For example, this shows four radiographically indistinguishable nodules. Two are bronchial carcinomas; one represents intralobar bronchopulmonary sequestration and the other a histoplasmic lymph node. Although all four lesions are close to the hilus, the lateral view showed them to lie either anteriorly or posteriorly, so they are included in our series of pulmonary nodules.

(slide) This is the lymph node which appeared typically tuberculous but was teeming with Histoplasma. They can be a cause of almost any pulmonary picture, including bronchiectasis, atelectasis, middle lobe syndrome, and so forth. Dr. Higginson this morning got into the subject of mediastinal granulomas in his paper on superior vena caval obstruction. Out of twelve resected mediastinal granulomas at the National Naval Medical Center, I have found Histoplasma in 4 of the lesions and 2 others had violently positive histoplasmin skin tests. Pathologists still manifest a firm reluctance to accept special staining methods for the demonstration of fungi. (slide) These are Histoplasma as seen in the methenamine silver nitrate technique of Gomori, a method with which we have had no experience but one about which Dr. Lorenz Zimmerman of the Armed Forces Institute of Pathology is extremely enthusiastic.

The final point of our paper concerns the favorable prognosis of peripheral bronchial carcinomas unaccompanied by symptoms and operated upon promptly. Survivorship in this group ranges around 75 per cent, a figure that coincides exactly with the one that Dr. Paulson has quoted for this series! Unfortunately, his splendid paper (Minnesota Med. 39: 127, 1956) appeared too late for inclusion in our review for the literature. Also, as the Mount Sinai group has repeatedly tried to bring out in the past and as Dr. Jones's group re-emphasized yesterday, lobectomy seems to be a perfectly acceptable cancer operation in properly selected cases.

# PULMONARY RESECTION FOR TUBERCULOSIS

## A Five- to Ten-Year Follow-up Study

James D. Murphy, M.D., Baltimore, Md., and James M. Davis, M.D. (by invitation), Jacksonville, Fla.

THE high morbidity and mortality rates associated with excisional therapy for pulmonary tuberculosis had resulted in virtual abandonment of that means of treatment prior to 1943. Its revival, stimulated by the report of Churchill and Klopstock[1] and later by the discovery of the bacteriostatic effect of streptomycin, is well known to those interested in thoracic surgery.

At the beginning of the chemotherapeutic era we,[2] as well as others, were impressed by the favorable early results obtained when the lesions of pulmonary tuberculosis were resected under the protection of streptomycin. It was generally agreed, however, that final evaluation of this means of therapy could not be made until a five- to ten-year follow-up study of these patients had been completed. We now have such a study on 148 patients who underwent 150 pulmonary resections during the years from 1946 to 1950.

### MATERIAL AND OBSERVATIONS

Eighty-three of our series were pneumonectomies and 67 were lobectomies or resections of units smaller than a lobe. Two of the group underwent a second resection giving a patient total of 148. The mean age of our patients was 28. The extremes were 20 and 56. There were 96 white and 52 Negro patients.

The racial distribution is of interest in that of the 52 Negroes who underwent resection 36, or 69 per cent, had pneumonectomy. This is in accord with the analysis of data presented at the Fourteenth Chemotherapy Conference[3] where it was shown that Negroes coming to surgery often require more extensive resections than white patients.

Streptomycin was the only antimicrobial drug used during the period covered by this series. Ninety-seven per cent of our patients received streptomycin during the pre- or postoperative period, or during both. One hundred and one of these were original treatment and 45 were re-treatment patients. The majority were given the drug for one week before and two weeks after operation, as was the custom at that time. Sensitivity studies were not available in sufficient numbers to be significant.

Eighty-five per cent of the pneumonectomy group and 58 per cent of the lobectomy patients were classified as far advanced. Ninety-one per cent had positive sputum during the immediate preoperative period. The high

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percentage of positive sputum patients in this series is in marked contrast to the present-day experience. At the Fourteenth Chemotherapy Conference[3] only 43 per cent of 1,133 patients, who had a resection during the previous year, were positive at the time of surgery. Forty of the patients in this study, or 27 per cent, were found to have positive smears or cultures at some time during the postoperative period of hospitalization. The conversion rate was higher in the pneumonectomies (77 per cent) than in the lobectomies (67 per cent), and preoperative thoracoplasty in the latter group did not apparently influence sputum conversion. Eighty-five per cent of the entire group had open lesions and all but 9 of these were sputum positive.

Thoracoplasty failure was the indication most commonly found, followed by destroyed lung, and pneumothorax failure. Thoracoplasty was performed in 41 per cent of our cases preoperatively, and 42 per cent postoperatively. No concomitant thoracoplasties were done.

Bronchopleural fistula occurred after 15 per cent of the subtotal resections and 26 per cent of the pneumonectomies. Chest wall sinus, early spread, wound infection, and delayed re-expansion followed in order of frequency. (Table I.) While the occurrence of a bronchopleural fistula must be regarded as a most serious complication, it was heartening to learn that many of these patients were salvaged. Thirty-two of our patients developed such a complication and when our study was concluded it was found that 44 per cent of these were at home with inactive disease. Empyema without fistula was encountered only three times. It should be noted that with the passage of time the number of patients who developed fistulas has increased. The rate found in the present survey was 21 as compared to 15 per cent which was reported in an earlier study of the same patients. Forty-six per cent of the entire group of resections were followed by complications, and a greater incidence was noted in our white patients.

TABLE I. COMPLICATIONS

| | LOBECTOMY SEGMENTAL | | PNEUMONECTOMY | | TOTAL | |
|---|---|---|---|---|---|---|
| | NO. | % | NO. | % | NO. | % |
| Bronchopleural fistula without empyema | 10 | 14.9 | 22 | 26.0 | 32 | 21.3 |
| Emypema without bronchopleural fistula | 0 | 0 | 3 | 3.6 | 3 | 2.0 |
| Chest wall sinus | 4 | 5.9 | 13 | 15.7 | 17 | 11.3 |
| Early spread | 3 | 4.5 | 10 | 12.0 | 13 | 8.6 |
| Wound infection | 6 | 8.9 | 7 | 8.4 | 13 | 8.6 |
| Delayed expansion or apical space | 8 | 11.9 | 0 | 0 | 8 | 5.3 |
| Others | 14 | 20.0 | 23 | 27.7 | 37 | 24.6 |

Eighteen patients (Table II) died in the hospital without an intervening discharge and 8 died following discharge. The surgical mortality was thus 9 per cent while the total rate was 17 per cent. The rate was higher in the pneumonectomy group than in those patients who had a lobectomy or a segmental resection. Three of the four operative deaths were due directly to

hemorrhage and one to cardiac arrest which occurred in the early stage of a secondary resection. The fourteen postoperative deaths were due mainly to bronchopleural fistula or the sequelae thereof, pneumonitis, spread, cerebrovascular accident, tuberculous meningitis, and other various causes. The eight nonsurgical deaths resulted from malignancies, heart disease, diabetes, accidents, and other causes not related to the surgery.

TABLE II. MORTALITY DATA

| | NUMBER OF OPERATIONS | SURGICAL | | | | NONSURGICAL | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|
| | | OPERATIVE | | POSTOPERATIVE | | | | | |
| | | NO. | % | NO. | % | NO. | % | NO. | % |
| Lobectomy—segmental | 67 | 2 | 3.0 | 4 | 6.0 | 3 | 4.5 | 9 | 13.5 |
| Pneumonectomy | 83 | 2 | 2.4 | 10 | 12.0 | 5 | 6.0 | 17 | 20.4 |
| Total | 150 | 4 | 2.7 | 14 | 9.3 | 8 | 5.3 | 26 | 17.3 |

Follow-up information was obtained from results of recent check-ups at Oteen or other VA Hospitals and Regional Offices, or from completed forms which were sent to all of the patients in the series who could not be accounted for by the former method. We have been able to obtain data on all of the 130 patients discharged from the hospital alive, giving 100 per cent follow-up.

The follow-up data are recorded on Table III. The "Excellent" category includes those who are at home with inactive disease, have essentially no symptoms, and are working. One must meet the same requirements to qualify for the "Good" group except that these patients are not working. A "Fair" result was used to include those who are home carrying out reasonably normal lives but with active disease or partially disabling symptoms and those who are in the hospital but without evidence of active disease. The "Poor" result patients are still hospitalized with active disease. There is some question as to the advisability of separating the nonworking from the working group since many of those classified as "Good" were discharged from our rehabilitation division with an eight-hour work tolerance. For this reason, we believe that these two groups should be combined. By doing so, we find that 107 patients, or 72 per cent, of the original group of 148 patients are classified as satisfactory. The 15 patients in the fair and poor groups, as well as the 26 who died, regardless of cause of death, are considered as unsatisfactory. No significant difference was noted in the percentage of satisfactory results when studied on the basis of race.

TABLE III. FOLLOW-UP DATA

| | LOBECTOMY SEGMENTAL | | PNEUMONECTOMY | | TOTAL | |
|---|---|---|---|---|---|---|
| | NO. | % | NO. | % | NO. | % |
| Excellent | 27 | 41.5 | 42 | 50.5 | 69 | 46.6 |
| Good | 23 | 35.4 | 15 | 18.1 | 38 | 25.7 |
| Fair | 2 | 3.1 | 8 | 9.7 | 10 | 6.8 |
| Poor | 4 | 6.2 | 1 | 1.2 | 5 | 3.4 |
| Dead | 9 | 13.8 | 17 | 20.5 | 26 | 17.5 |
| Total | 65 | 100.0 | 83 | 100.0 | 148 | 100.0 |

Late reactivation has been a disturbing feature of this follow-up study. This problem was emphasized by Sweet[4] in his report of cases treated by resection during the pre-streptomycin period. An over-all total of 25 patients, or 17 per cent, developed a late reactivation. Twelve of these recovered, 7 on medical therapy and 5 after secondary resections. Eleven treated medically remain active, one patient died of his disease and another following a second resection.

## DISCUSSION

This series of resections was accomplished during the years immediately following the introduction of streptomycin. Judged by present standards of chemotherapy, the duration of treatment was inadequate. A large percentage of the patients had far-advanced disease, open lesions with positive sputum, and were failures of other means of therapy. Many would fall in the category of salvage cases. Even so, we find that 72 per cent of 148 patients who underwent a resection, and 82 per cent of those who were discharged from the hospital alive are at home with inactive disease.

Developments in the field of chemotherapy since 1950 have been dramatic. The addition of new drugs and improved methods of application of the older ones have resulted in such a decrease in the size of the lesions and extent of resection necessary for their removal that it is impossible to compare surgery as done at the present time with the early series, or to make a prediction of results to be expected from such surgery. Drug resistance is still another important factor to be considered. It is felt, however, that data reported in this study are of value as a record of results achieved by resection during the pioneer days of streptomycin therapy.

## SUMMARY

1. A series of 150 resections for pulmonary tuberculosis done between October, 1946, and April, 1950, is reported. Eighty-three of these were pneumonectomies and 67 were lobectomies or resections of smaller units than a lobe.

2. The operative mortality was 2.7 per cent and the total mortality was 17.3 per cent.

3. Our study includes 100 per cent follow-up.

4. Seventy-two per cent of the entire group, and 82 per cent of the patients who left the hospital alive have obtained satisfactory results.

5. Negroes often required a more extensive resection than white patients but did as well or better insofar as mortality, morbidity, and long-term follow-up were concerned.

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## Discussion

PROFESSOR J. F. NUBOER, Utrecht, Holland.—First of all, I want to thank you very much for the invitation to attend this meeting. It is an excellent one indeed.

I should like to say a few words in discussion of the paper of Dr. Davis, which I appreciated very much. I congratulate him on his excellent results.

As you perhaps know, tuberculosis in Holland increased greatly after the war. Now the disease is under control again, the mortality rate for 1955 being 6.6 per 100,000. Our policy with regard to the treatment of tuberculosis differs somewhat from that in your country. About 30 per cent of our sanatorium patients are operated on, about the same percentage as here. However, before the operation we give as little streptomycin as possible. In every case where the possibility of an operation is foreseen, streptomycin is given in the preoperative phase only under special indications, for example, in case of hematogenous spread or tuberculous bronchitis or extensive disease which is not possible to control by medical treatment alone.

Para-aminosalicylic acid (PAS) treatment in the Dutch sanatoriums is a very rigorous regimen. During the preoperative phase, the patient gets in addition, para-aminosalicylic acid and isonicotinic acid hydrazide (INH). After the operation, streptomycin is given for about three months during the aftertreatment in the sanatorium, which lasts for at least six to eight months.

Resection therapy for lung tuberculosis was started in Holland in 1946. In the beginning, we had no streptomycin or other antituberculosis drugs. The results were disappointing at first, but as soon as we could use streptomycin there was much improvement.

(slide) Until the first of March, 1956, in the surgical department of Utrecht University Hospital, 1,173 lung resections were performed, 1,161 under cover of streptomycin and other drugs.

(slide) The first 12 patients were operated on without streptomycin; the mortality was 25 per cent. In the other 1,161 operated on under cover of streptomycin, PAS, and INH, the mortality was 1.63 per cent. For the entire series, the mortality was 1.87 per cent. In 6.6 per cent of the cases, we saw spread or reactivation; most of the cases were cured by different means.

The late mortality in the series was 1.9 per cent. Some died of cancer, some as a result of accidents, several as the result of the original disease. Because practically always reactivation and spread were seen during the first months after operation, we are convinced that the three- to ten-year results can be evaluated just as the five- to ten-year results. Our follow-up is 100 per cent, which is possible in a small and densely populated country like Holland.

(slide) In the series of patients operated on five to ten years ago, 98.5 per cent of the surviving and 85.7 per cent of the total group have negative sputum on culture, and are working or able to work.

(slide) The results in the group operated on three to ten years ago are about the same, 97.5 per cent of the surviving and 90.5 per cent of the total having negative sputum on culture.

In Holland, we are rather satisfied with the results of resection therapy in lung tuberculosis.

DR. JOHN MAXWELL CHAMBERLAIN, New York, N. Y.—Before this Association, during the last nine years, we have reported on our results in segmental resection. First, we reported on the first 100 cases, later on 200 cases and, finally, three years ago on the follow-up of 300 cases followed for two to five years. In view of the fact that our first segmental resection was done in 1947, we do not have a ten-year follow-up such as that of Dr. Murphy and Dr. Davis, but we do have a five- to nine-year follow-up on 150 cases, and Dr. Klopstock has just sent me in a letter the last word on the first 161 cases on which we performed segmental resection between 1947 and 1953.

There are now 135 of the 150 we were able to follow; 135 classified as living and well, with negative cultures, negative x-rays, and working or capable of working. Six patients

are living with disease. I believe our percentage would be 90 per cent living and well; 3 per cent living with disease; and 10 patients or 7 per cent dead. Of the 10 who died, 4 died of tuberculosis and 6 died of unrelated causes.

I realize that this is only one aspect of the surgical treatment of this disease, but the figures seem to be quite good and I suppose that means, in comparison with the figures you have just seen in which the patients had so far-advanced disease that it was necessary to do pneumonectomy or lobectomy, that these patients convinced us that the earlier you can treat the disease surgically the better will be our long follow-up results.

DR. JOSEPH W. GALE, Madison, Wis.—I thought it might be interesting at this time to refer to a group of patients, some of whom were operated upon before the era of antimicrobial therapy. We reported 80 patients in 1949 who had been operated upon and only about one third of whom had the advantage of streptomycin treatment.

(slide) Our results are different from those of the essayist in the early cases. I think this is probably because we were working on the burned-out cases, since we had very few patients with acute disease in the bronchi. This group includes 1,165 cases who have been followed over a period of one to ten years. You will note the predominance of far-advanced cases in this group. The minimal is the smaller group. We have been told that we do not have much tuberculosis in Wisconsin and that most of it is minimal. I believe these figures prove differently.

(slide) Our chief complication following surgery, however, in spite of the fact that we have tried to check the bronchi carefully, has been bronchopleural fistula. Our figures show that 20.5 per cent of the cases developing fistula died of sepsis or some other type of infection.

(slide) The total operative deaths in this group: following pneumonectomy, 21; following lobectomy, 13; following segmentals, 2—both accidental, but nevertheless they died and we have to figure they are an operative mortality. We had 36 operative deaths in this group of 1,165.

(slide) These are the nonoperative deaths which occurred over ninety days after the patient was discharged from the hospital, and were not involved with the surgery in any way whatsoever. They exceeded the operative deaths by three.

(slide) So, in summary, we have 1,165 cases; operative deaths, 36; nonoperative deaths, 39. Fifty of these patients have not been followed recently enough to be included. It takes considerable time to follow patients over a ten-year period when you get into figures above 1,000.

DR. MURPHY (Closing).—I merely wish to re-state the fact, which Dr. Davis emphasized, that it is impossible to compare results in those early days with present-day results. At that time, you will remember, we thought that streptomycin was going to be simply an adjunct to surgery. It now appears that the process has been reversed, and that surgery is, by and large, an adjunct to the chemotherapy of tuberculosis. The results we obtained at Oteen, while not quite as good as those quoted by the various discussants, indicate we believe that resection for tuberculosis is a good method of treatment and is here to stay.

# THE ROLE OF CHRONIC OCCULT POSTRESECTION FISTULAS IN THE REACTIVATION OF TUBERCULOSIS: PATHOGENESIS AND TREATMENT

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IN CONSIDERING the etiology of tuberculous reactivation following pulmonary resection, little attention has been given to the possible association of chronic occult bronchial fistulas. With reports of resection for pulmonary tuberculosis ever increasing, we believe this important postoperative phenomenon should be given additional emphasis and amplification as a definite clinicopathologic entity.

In a recent paper, Franz and Murphy[1] described 4 cases of masked bronchial fistulas. Only one of these patients, however, had evidence of persistent tuberculous activity. We prefer the term "occult," rather than masked, as suggested by Murphy. While the average postoperative bronchopleural fistula is overt in its manifestations, the occult fistula is characteristically silent. Following surgery, such a fistula may be present for a period of two years or longer (Fig. 1), while the patient remains completely asymptomatic.

## MATERIAL

A study of 8 patients, with postresection tuberculous infection of the operative site, forms the basis of this report. Because the clinical pattern, type of primary and secondary operation, pathologic and bacteriologic findings were similar for the entire group, they will not be described individually.

At the time of the original resection, the patients were being treated with drug combinations, consisting of two major drugs in 4, and three major drugs for the other 4 (Table I). A re-treatment program had been advised in 7 cases to achieve sputum conversion, in spite of persistent cavitary disease. One patient arrived at the open negative state as a result of original chemotherapy. Four of the remaining 7 patients were sputum negative prior to surgery as the result of a re-treatment drug regimen. One patient had received thirty months of chemotherapy and had ancillary collapse measures of both pneumoperitoneum and pneumothorax before resection was contemplated. The reappearance of a left upper lobe cavity, following abandonment of the pneumothorax, led to a recommendation for pulmonary resection.

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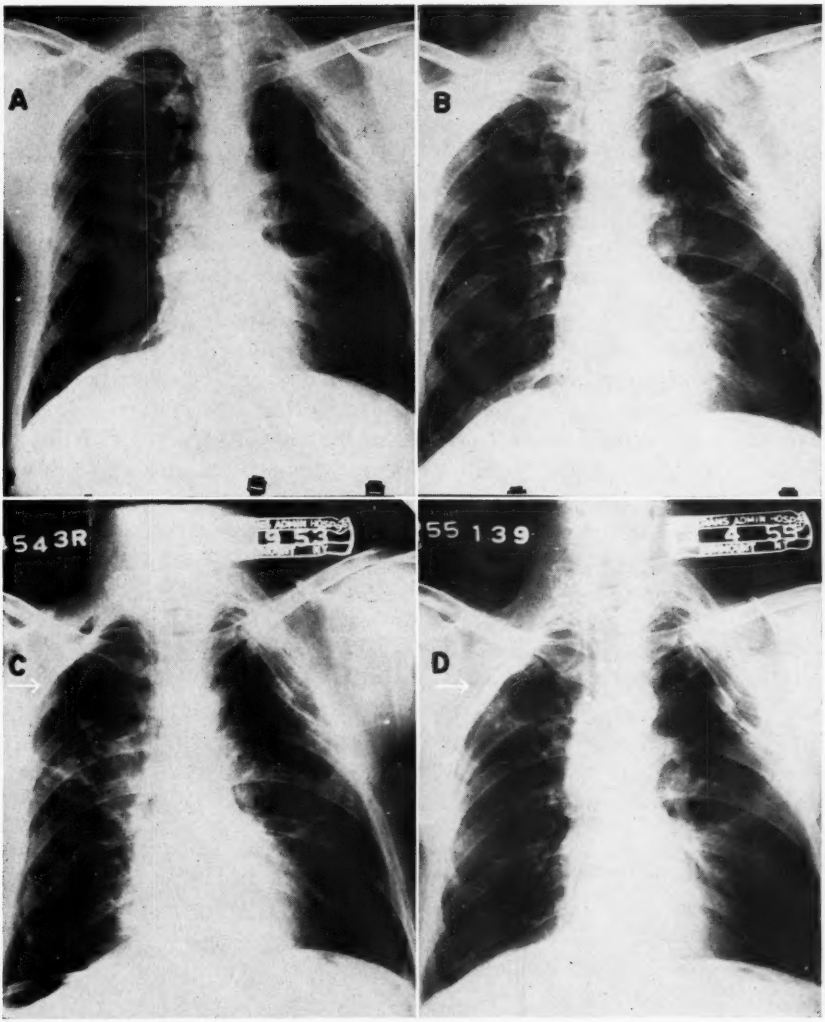



Fig. 1.—*A*, Preoperative, 2 cm. cavity, posterior segment, right upper lobe.

*B*, Preresection thoracoplasty, right.

*C*, Nine days postresection (apical and posterior segments), showing persistence of local pneumothorax.

*D*, Two years after bisegmental resection. Pneumothorax pocket in exactly same area as immediately postoperatively; sputum continuously positive.

TABLE I. CHRONIC OCCULT FISTULAS
DATA PRIOR TO RESECTION—8 PATIENTS

| CHEMOTHERAPY | | | | |
|---|---|---|---|---|
| COURSE | | MAJOR DRUGS | | DURATION |
| Original treatment | 1 | SM,* PAS† | 3 | Four to 30 months |
| | | INH‡ added between resections | 2 | |
| Re-treatment | 7 | SM, INH | 1 | |
| | | Viomycin added between resections | | |
| | | SM, PAS, INH | 4 | |
| | | Viomycin added between resections | | |

*SM—streptomycin.
†PAS—para-aminosalicylic acid.
‡INH—isonicotinic acid hydrazide.

Only one of the group had tubercle bacilli completely susceptible to both drugs in the last preoperative or preconversion sputum (Table II). The significance of organisms resistant to one or more drugs in the sputum of the remaining 7 patients was not appreciated at this time. A cavitary lesion was present in the upper lobe of 7 patients at the time of surgery, while in one patient a pre-existing cavity had closed some two months before resection.

TABLE II. CHRONIC OCCULT FISTULAS
DATA PRIOR TO RESECTION—8 PATIENTS

| BACILLARY RESISTANCE IN PREOP. SPUTUM | | SPUTUM STATE AT OPERATION | | STATUS OF LESION | |
|---|---|---|---|---|---|
| Susceptible | 1 | Negative | 5 | Cavitary | 7 |
| One drug | 3 | Positive | 3 | Noncavitary | 1 |
| Two drugs | 2 | | | | |
| Three drugs | 2 | | | | |

In every resection performed in this group, an effort was made to excise all palpable disease in the unilateral lung. This was accomplished, with the exception of fine 2 to 3 mm. scattered seeding, by primary resections ranging from multiple wedges up to a maximum of two segments (Table III).

TABLE III. CHRONIC OCCULT FISTULAS
POSTRESECTION TUBERCULOUS REACTIVATION—8 PATIENTS

| TYPE PRIMARY RESECTION | | BACILLARY RESISTANCE IN SPECIMEN | | TUBERCULOUS REACTIVATION POSTOPERATION |
|---|---|---|---|---|
| One segment | 2 | Susceptible | 1 | Three weeks to 3 months |
| Two segments | 4 | One drug | 1 | |
| Multiple wedges | 2 | Two drugs | 3 | |
| | | Three drugs | 3 | |

At the time of resection, in each instance there was no gross spillage of caseous material, and it was believed that the tuberculous lesions had been completely encompassed. There *was no macroscopic evidence of endobronchial disease* in any case, either by *preoperative bronchoscopy or observation at the time of bronchial transection.*

In each patient, tubercle bacilli were recovered by culture from the resected material (see Table III). Again, in only one specimen were the or-

ganisms susceptible to the drugs being administered. It is important, and this was realized only in retrospect, that equivalent or *greater* resistance was found in the organisms recovered from tissues than was present in the preoperative sputum cultures. Moreover, half of this group had negative sputum for three to five months prior to their first resection (see Table II).

### DIAGNOSIS AND CLINICAL SYNDROME

The absence of any subjective symptoms, directly attributable to a postresection fistula, increases the difficulty of diagnosis. One of our patients failed to gain weight postoperatively, in spite of nutritional supplements. The remaining 7 were completely asymptomatic.

The ordinary congestive changes in the lung, resulting from the trauma of wedge or segmental resection usually resolve in varying degree during the first postoperative month. Persistence of a hazy density beyond this period suggests more than an operative defect (Fig. 2). The development of a semiannular shadow, usually without an air-fluid level, may indicate an occult fistula (Figs. 2-5). The respective contribution of parenchymal induration or pleural fluid to the density increases the difficulty of radiologic interpretation.

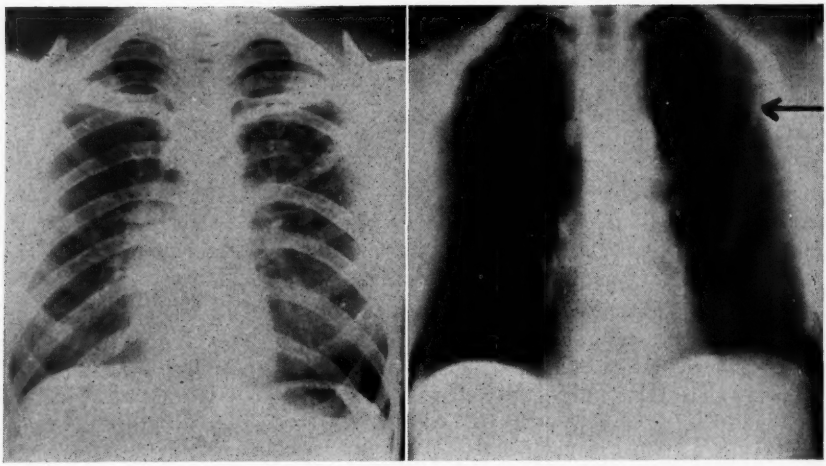
The fact that a pseudocavity may be bounded on all sides by parenchyma, or on the third side with parietal chest wall, makes the use of planigrams almost mandatory for the recognition of these defects. Body section planigraphy, at the level of the segmental stump (see Figs. 2, 4, 5) may reveal a pyramidal or annular radiolucency. This configuration can easily be ignored on the routine posterior anterior chest film.

A further diagnostic aid in the demonstration of an occult fistula and parafistulous space is bronchoscopy and bronchography. Bronchoscopic inspection of the segmental stump may reveal several black silk sutures embedded in gray, edematous granulation tissue, rather than a well-healed stump. Instillation of radiopaque media may show partial filling of the parafistulous cavity, with clubbing or a blob of oil just distal to the level of segmental stump transection (Figs. 5, 6).

Tuberculous reactivation almost invariably was suspected radiologically before bacilli reappeared in the sputum. This situation, of course, pertains only to those patients operated upon while in the sputum negative state. Bacteriologic relapse in the presence of serial x-ray evidence of slowly resolving infiltration, at or near the resection site, leaves little doubt of tuberculous reactivation.

In this group of reactivations, associated with occult fistulas, both x-ray and bacteriologic evidence was confirmatory by the third postoperative month (see Table III).

While not so dramatic as the postoperative reappearance of bacilli seen in the open negative patients, the failure of a resection to alter a preoperative positive sputum may be sufficient evidence to suspect a tuberculous infection in the operative site, particularly if the contralateral lung is free of active disease.



*A.* *B.*

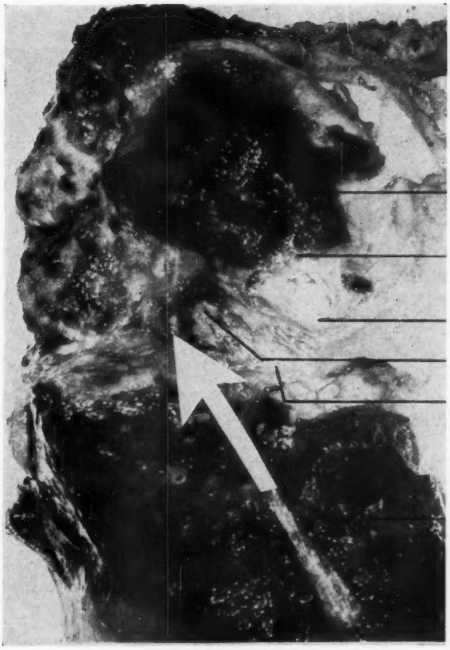
*C.*

Fig. 2.—*A*, Two months after resection of apicoposterior segments. Patchy infiltration persists in left upper lobe.

*B*, Planigram showing semi-annular shadow at resection site.

*C*, Gross specimen, left upper lobe, from secondary resection. Pseudocavity (4 cm. in diameter) lined with necrotic tuberculous granulation. Arrow indicates occult fistulas of segmental stumps.

*A.* *B.*




*C.*

Fig. 3.—*A*, Preoperative x-ray revealing twin cavities in left upper lobe.

*B*, One month following apicoposterior segment resection. Semi-annular pneumothorax persists in area of resection.

*C*, Gross specimen, left upper lobe, from post-mortem. Pseudocavity (6 cm. in diameter) full of blood clot and lined with tuberculous tissue. Arrow indicates occult fistula and site of erosion into pulmonary vein causing fatal hemorrhage.

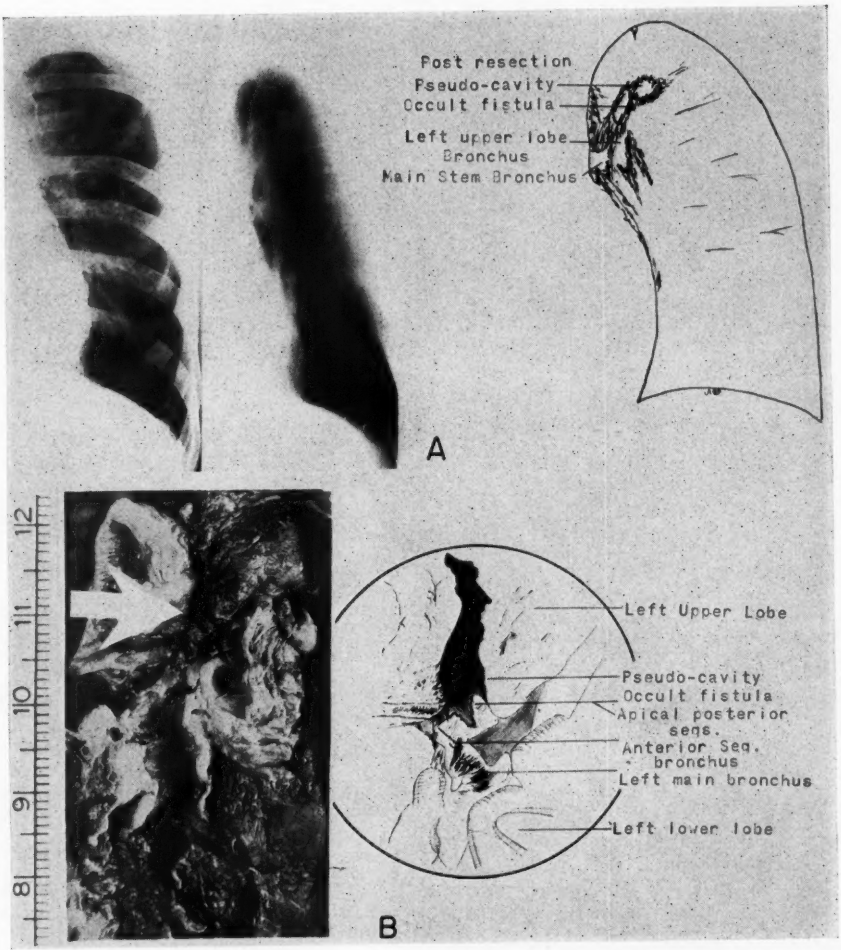
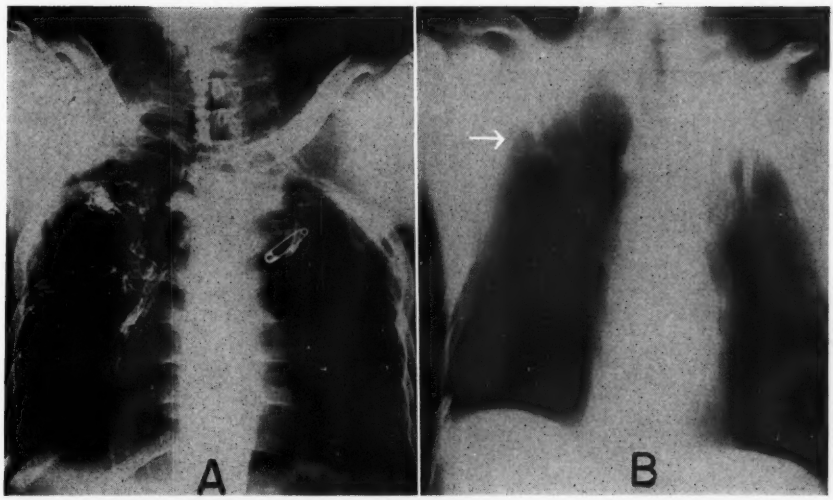



Fig. 4.—*A*, X-ray, planigram and diagram, six months after operation, showing small (2 cm.) cavity at site of apicoposterior segment resection.

*B*, Gross specimen, left upper lobe, removed at secondary resection. Arrow and diagram indicate 2 cm. postresection defect and occult segmental fistulous stumps.



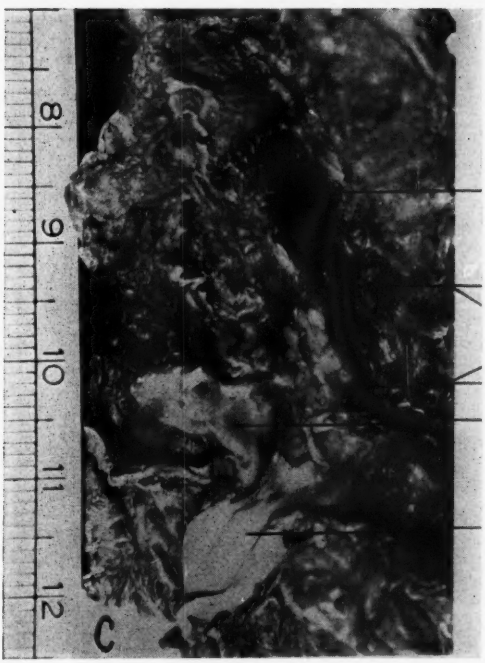




Fig. 5.—*A*, Bronchogram, six months after resection of apicoposterior segments, right upper lobe, revealing puddling of oil just distal to segmental fistulous stumps.

*B*, Planigram, six months postoperation, showing annular shadow with air bronchogram of segmental bronchial stumps at apex of defect.

*C*, Gross specimen. Remainder of right upper lobe removed at secondary resection. Pseudocavity, with many black silk sutures, in wall connecting directly with infected fistulous tract.

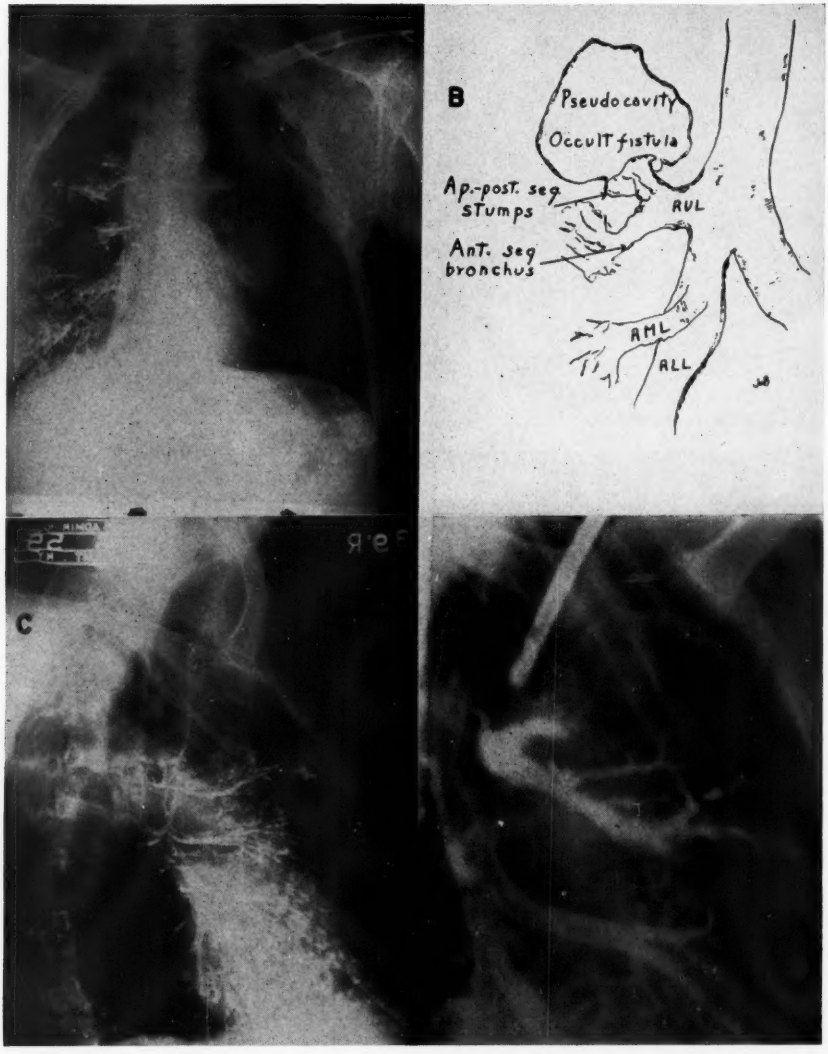



Fig. 6.—*A*, Bronchogram, two years after bisegmental resection, outlining configuration of pseudocavity.

*B*, Diagram showing semi-annular shadow with occult fistulas at apex.

*C*, Oblique bronchogram.

*D*, Spot bronchogram revealing detail of puddling at segmental fistulous stumps and filling of anterior segment bronchus.

## PATHOGENESIS

In our experience, the postresection phenomena of a chronic tuberculous fistula and a parafistulous space are due to two factors: mechanical and infectious. The lung adjacent to the wedge-shaped defect resulting from a segmental excision must expand and undergo readjustment during the immediate postoperative period. The manner in which this takes place depends a great deal on the relation of the operative area to the chest wall, or the expandibility of adjacent parenchyma and the measures which the surgeon takes to aid nature's reconstitution of the lung.

A space remaining at or near the operative site may fill with blood or serofibrinous exudate. This fluid may be an ideal culture medium for a local tuberculous empyema. As (drug resistant) bacilli flourish, the segmental bronchial stump, originally adequately closed by sutures, can break down.

Once bronchial communication has been established, and the liquid contents sloughed, the morphology and behavior of the new cavity is quite similar to a typical tuberculous cavity. Designated a pseudocavity because one of the boundaries may be parietal pleura rather than completely enclosed by lung, this infected space may be larger than the cavity for which the primary resection was performed (Fig. 7).

*Macroscopic Findings.*—Gross examination of these infected operative sites reveals a rather uniform appearance (Figs. 2-5, 7, and 9*A*). The inner surface is granular, irregular, and lined for most of its extent by grayish-red necrotic tissue. The bronchial stumps are dirty and unhealed. Black silk sutures scattered about the inner wall are a common finding in most of the specimens. There may or may not be a well-delineated wall between the infected pseudocavity and the adjacent lung tissue.

*Microscopic Findings.*—A common finding in six of the eight secondary specimens (seven obtained at secondary resection and one at post-mortem) was a cavity wall lined with necrotic material of variable thickness. In some regions, this necrotic zone was extremely wide and within it the former structure of the lung parenchyma may still be discernible. Beyond the necrotic tissue there was a zone of scar tissue which varied considerably in thickness and cellularity in different areas, but this zone of fibrous tissue appears to be continuous between the necrotic tissue and the adjacent lung parenchyma. This finding indicates that the tuberculous disease in the lung can hardly have arisen by a penetration of the infection into the lung substance.

The major factor in the etiology and dissemination of tuberculosis in these patients is found in the nature of the fistulous tract. Those specimens of particular interest which contribute to an understanding of the pathogenesis, will be described briefly, but in detail.

## CASE REPORTS

CASE 1.—(Fig. 2.) Sections through the fistulous tract (Fig. 8, *A*) that is connected with the upper lobe bronchus show almost the entire surface to be necrotic tissue that is quite heavily infiltrated with neutrophils. Beyond this necrotic layer, there is a well-formed scar which separates the tract from the surrounding tissue. The larger bronchial

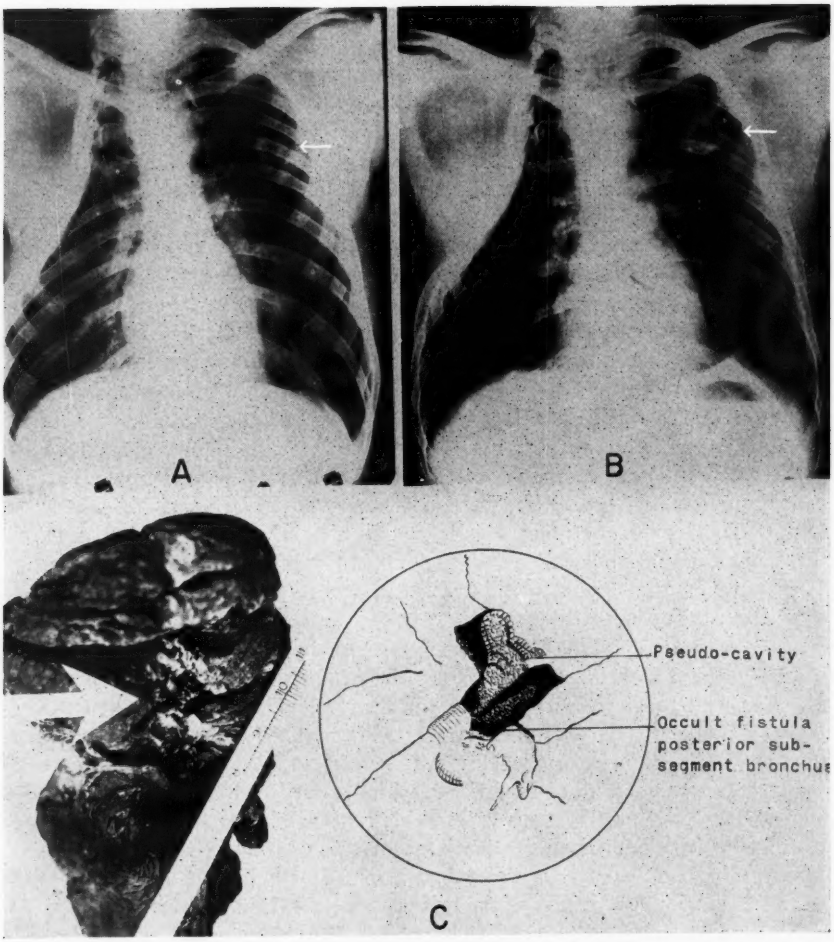



Fig. 7.—*A*, Two centimeter cavity in posterior segment, left upper lobe, preoperatively. *B*, Three centimeter pseudocavity, at site of wedge resection, four months after operation. *C*, Gross specimen, superior division, left upper lobe, removed at secondary resection, showing 3 cm. infected operative site and occult tuberculous fistula.

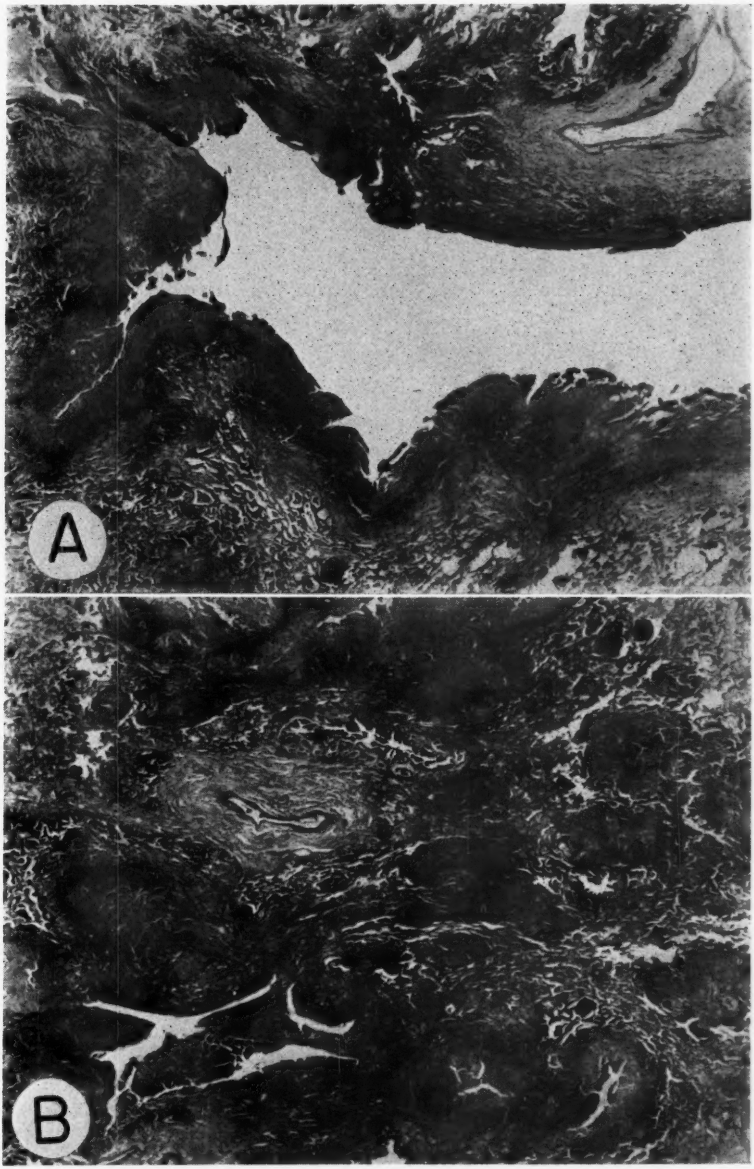



Fig. 8.—*A*, Photomicrograph (×15; reduced 1/6). "Occult fistulous tract"—the entire inner surface is necrotic and heavily infiltrated with neutrophils. Beyond necrotic zone, there is a zone of scar tissue, separating the tract from surrounding tissues.

*B*, Photomicrograph (×15; reduced 1/6). Section of lung adjacent to fistulous tract. Many foci of tuberculous pneumonia. Fresh lesions, both necrotic and non-necrotic, from bronchial dissemination. Large bronchus in lower left quadrant contains necrotic debris and shows necrosis of bronchial wall in these areas.

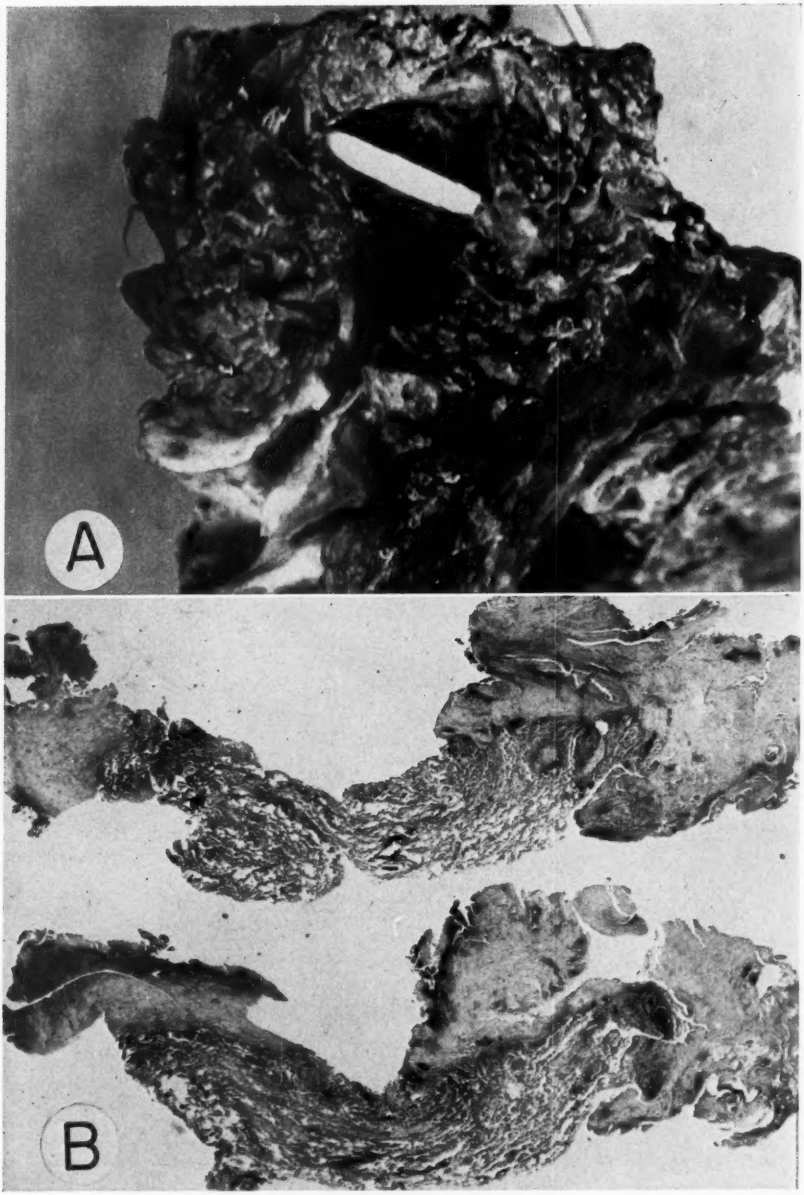



Fig. 9.—*A*, Gross specimen, remainder of right upper lobe (same case as Figs. 1, 6) revealing occult fistulous tract leading directly to pseudocavity at segmental resection site. *B*, Photomicrograph (×15; reduced ⅛) through tuberculous fistulous tract, with the surface necrotic in sizable areas. Two sutures are seen and around both there is necrotic tissue.

structures in the hilar region show *no evidence* of necrotic endobronchial tuberculosis, but all show considerable lymphocytic infiltration of the mucosa.

There are several foci of suture material in the tissue adjacent to the sinus tract. Most of these show no inflammatory reaction, and are surrounded by scar tissue. However, in this hilar portion, two sutures have tuberculous lesions with necrosis about them. This situation suggests that there had been an implanted tuberculous infection at the time of the previous surgery.

CASE 2.—(Figs. 1, 6, 9.) Sections through the fistulous tract (Fig. 9, *B*) show considerable scar tissue, with the surface being necrotic in sizable areas. In this portion, there are two sutures, and around both there is necrotic tissue. No evidence of tuberculous infection of the larger bronchial branches in the hilar region is found.

*Summary of Pathology.*—It appears that, in this group of seven specimens (secondary resections), the tuberculous involvement is related to an *implantation infection* at the time of the primary resection, rather than to a necrotic endobronchial tuberculosis that was present at the time of surgery. The presence of suture material, directly involved in the necrotic tuberculous disease, is additional evidence to suggest that implantation infection had occurred at the time of the first operation.

In four of the specimens, recent foci of lobular pneumonia were found in the parenchyma adjacent to the fistula (Fig. 8, *B*). In several lesions, bronchi, in direct communication with these areas, contained necrotic debris. These lesions, apparently, are the result of endobronchial dissemination from the sinus tract. Since it is recorded that the surgeons removed all palpable disease in the primary resection, it is probable that *all of the recent tuberculous disease in these specimens resulted from endobronchial dissemination from and subsequent to the formation of the tuberculous fistulous space.*

## DISCUSSION

Stemmermann, Daniels, and Auerbach[2] have studied the pathogenesis of bronchopleural fistulas following excisional therapy for pulmonary tuberculosis. They mention 9 cases of postoperative fistulas, 5 of which are described in detail. Four of these five fistulas occurred after pneumonectomy or lobectomy, only one following a segmental resection. Again, four of these five specimens were studied at necropsy rather than at secondary thoracotomy. They believed the mechanism of the fistulas could be considered under two causes; either erosion by an extrinsic lesion, as a local tuberculous empyema or lymph node, or factors intrinsic to the bronchus, as poor closure, extension of ulcerative endobronchitis or delayed infection of the stump from parenchymal lesions. From a consideration of the time relationships in the clinical course and the pathologic evidence, they concluded that, in most instances, a tuberculous empyema had preceded and contributed to the formation of the fistula.

It may be recalled that none of these cases received what would be considered satisfactory chemotherapy by present standards, and each resection was carried out in the presence of known or probable drug resistant bacilli.

The high incidence of tuberculous bronchial disease was well known in the so-called pioneer years of chemotherapy. Overholt and co-workers[3] (1949)

reported finding bronchial involvement in 64.5 per cent of resected post-thoracoplasty specimens, while Auerbach[4] (1949) found an incidence of 42.1 per cent in one thousand consecutive autopsies on tuberculous patients.

More recently (1953) Olson, Jones, and Angevine[5] discovered some degree of endobronchial tuberculosis in 40 per cent of 602 surgical specimens. Roll[6] carried out a study of bronchial stump ulceration following resection, and noted an incidence of 24 per cent in four hundred resections. A significant finding in this series was the prevalence of stump ulceration in those patients who had drug resistant bacilli at the time of surgery.

Medlar[7] has found that true "ulcerative" tuberculous endobronchial disease is uncommon. The majority of bronchitis is a superficial mucositis resulting from the sloughing of necrotic debris from an adjacent parenchymal cavity. When the actual sloughing is reduced or eliminated by collapse, resection or chemotherapy, the secondary bronchitis subsides.

We do not concur in the rather widespread belief that most bronchopleural fistulas result from transection through unrecognized tuberculous endobronchial disease.

The acute or frank fistula in the early postoperative period may result from mechanical factors relating to the remaining lung, or to the blood supply or closure of the stump. Chronic fistulas, whether overt or occult, do not necessarily result from, or are associated with, tuberculosis. Several of our patients, and several in Murphy's report, were seen in many months, and even years, after resection, with hemoptysis or excessive cough, yet with no evidence of bacteriologic relapse.

## TREATMENT

No secondary measures, whether re-treatment with new drugs, postresection thoracoplasty, or secondary resection, are as important as the original prevention of these medical-surgical failures. Our entire concern in this study has been an analysis of the factors which predispose to this complication. These will be summarized:

1. *Chemotherapy Control.*—Previous experience with pulmonary resection in patients with closed or open (cavitary) lesions, whether sputum negative or positive at the time of surgery, has yielded uniformly good results, provided drug coverage was effective.

With the exception of the patient herein reported (see Table II) who demonstrated tuberculous reactivation following excision of a noncavitary lesion, there have been no other instances of tuberculous complications in a group comprising 80 patients with closed lesions.

The results of resection in a larger group of 150 patients, who had residual annular shadows and negative sputum for three months prior to surgery, the so-called "open negatives," were equally satisfactory.[8] However, in the past three years, 8 patients treated with multisegmental resections, have demonstrated both x-ray and bacillary relapse postoperatively. In 5 of these patients, included in the present study, the tuberculous reactivation was associ-

ated with an occult segmental stump fistula. The remaining 3 patients had x-ray evidence of exudative disease in the parenchyma adjacent to the resected segments. Diagnosis of an occult fistula was not certain, however, and for various reasons, secondary resection was not performed.

A uniform finding in each patient with this complication was the demonstration of tubercle bacilli in the resected specimen, with significant resistance to one or more drugs.

Review of the bacteriologic data of each patient revealed beginning resistance to one or more drugs prior to the time of sputum conversion. Because of the absence of tuberculosis morbidity in the open negative patients with susceptible organisms prior to surgery, or in the resected specimen, it was felt that effective chemotherapy was the most important consideration for a safe resection.

Those patients who had both cavitary lesions and positive sputum at surgery exhibited a similar correlation.[9] In other words, those patients with bacilli resistant to one or more drugs had two to three times the incidence of postresection tuberculous complications as those with susceptible organisms.

Thus, the incidence of tuberculous morbidity in each group, whether sputum positive or negative, and whether open or closed lesions, although almost insignificant in the latter, appears to parallel the ultimate effectiveness of the antituberculous agents.

2. *Type of Resection.*—Because of the anticipated and actually higher incidence of tuberculous complications in patients with poor antimicrobial control, we believe certain operative precautions should be taken with these patients, which do not appear necessary in the group with completely susceptible organisms. These will be summarized:

1. Avoid spillage of necrotic tuberculous material. (In this event, copious irrigation of pleural space, change of gloves and suction tip.)

2. Avoid wedge or segmental resections which allow narrow clearance of cavity-bearing areas and may cut across heavily seeded intersegmental planes.

3. Insurance that remaining lung tissue will rise up over and adhere to the area of the bronchial stump.

4. Measures to encourage prompt expansion and eliminate space problems; (a) reconstitution of incomplete fissures, (b) division of inferior pulmonary ligament, and (c) selective use of pneumoperitoneum.

Since the chronic occult fistulas described in this report were a complication of resection therapy, it was with some trepidation that secondary resections were advised. As mentioned, one patient died of pulmonary hemorrhage before the occult fistula was diagnosed or resection could be planned. The second patient, the only one of the group with susceptible bacilli in tissue culture, had a segmental resection as a successful secondary operation when a deep wedge had been done primarily. In the remaining 6, all with resistant bacilli in the primary specimen, secondary lobectomy was the only alternative. Each operation was difficult because of inflammatory reaction near the segmental stump and pulmonary artery. In one instance, an uncontrollable laceration in the artery necessitated a pneumonectomy (Table IV).

TABLE IV. CHRONIC OCCULT FISTULAS
SURGICAL TREATMENT—TUBERCULOUS REACTIVATION

| TYPE OF SECONDARY RESECTION | | CURRENT STATUS | |
|---|---|---|---|
| None | 1 | Dead | |
| Segment | 1 | pulmonary hemorrhage | 1 |
| Lobectomy | 5 | Inactive | |
| Pneumonectomy | 1 | six to 36 months | 6 |
| | | Active | |
| | | contralateral side | 1 |

The unexpected success of lobectomy in arresting unilateral disease after a postresection tuberculous reactivation, strengthened our impression that whenever this type of bacteriologic background exists, lobectomy should be the choice at primary resection. Although the fistulous tracts were all infected with tuberculosis at the segmental stump level, it is significant that resection just a few millimeters lower; for example, at the level of the lobe bronchus did not result in any fistulas or stump ulcers.

The present status of this small group is of interest (see Table IV). Six of the group have been inactive for periods ranging from six to thirty-six months. One patient has a small superior segment cavity in the contralateral lung and is being retreated with cycloserine.

## SUMMARY AND CONCLUSIONS

1. Eight cases of chronic occult bronchial fistulas are described following segmental excision of all palpable tuberculous lesions. Each fistulous tract became infected and resulted in the endobronchial dissemination of new disease in the adjacent lung.

2. The sputum of 5 patients had been negative by culture for at least three months prior to resection. Seven of the group had culture positive specimens, which yielded tubercle bacilli with equivalent or greater resistance patterns than were apparent before operation.

3. The clinical syndrome, which is notable for its absence of subjective symptomatology, is described. Recognition that such complications may occur in patients with open lesions, regardless of the sputum state preoperatively, particularly when drug resistance is apparent, will facilitate the diagnosis. Other diagnostic aids are discussed.

4. The role of a local postresection space and uncertain antituberculous drug control in the pathogenesis of chronic tuberculous fistulas and adjacent parenchymal reactivation is described.

5. Careful microscopic study of the specimens obtained at secondary thoracotomy, and the known duration of the new tuberculous lesions, indicates that all occurred subsequent to spillage from the fistulous tract. There was no evidence of endobronchial tuberculosis at the level of bronchial transection in the primary specimens.

6. Many patients with various degrees of resistant bacilli evident preoperatively do not have tuberculous complications. However, the majority of patients with these complications are found in this group.

7. This study reaffirms the importance of careful "tailored to bacteriology" surgery at the time of resection in patients with uncertain drug control. A wide, clean type of resection, usually a lobectomy, was immediately successful in this group with occult fistulas when a previous bisegmental excision had failed.

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## DISCUSSION

DR. JOSEPH GORDON, Albuquerque, N. M.—It pleases me very much to see this presentation coming out of Sunmount. In 1954, at the Montreal meeting, some of you may recall that in discussion of one of the papers, I presented the information that bronchography was important as an adjunct in demonstrating a bronchial communication in any persistent space following resection. At that time, I had left Ray Brook shortly before and was then associated with the work at Sunmount as well, but was unable to present the paper formally. However, we did continue with the work at Albuquerque at the Veterans Hospital, and have found that it is indeed relatively easy to demonstrate a bronchial communication in most cases in which the pneumothorax persists. This is an important feature, because as you may have seen here, and as we have had experience in the need to correct this asymptomatic space. As time goes on, infection may be extended to the point where re-operation requires extensive surgery, even to pneumonectomy, to solve the patient's problem. In any instance, where there is delayed expansion of the lung or persistence of space, or almost re-expansion of the space but a small strip remains, it is most important to try to demonstrate by every means possible, chiefly by bronchography, the presence or absence of a bronchial fistula. It is even important in instances where a so-called tailoring thoracoplasty is used to obliterate the remaining space, that care be taken to demonstrate whether or not the space still persists under the thoracoplasty. This can be done with the aid of contrast medium. I believe that in any instance where the space persists, the diagnosis of presumptive bronchial fistula should be considered until such time as it is completely ruled out. I am pleased to see this work so well presented today.

DR. ALFONSO TOPETE, Guadalajara, Mexico.—I appreciate very much the opportunity of discussing this interesting paper. I believe the problem of bronchial fistula after pulmonary resection is still present, mainly in resection of tuberculous pulmonary tissue, and especially in lobectomies and pneumonectomies.

I should like to say a few words about an experimental work we have been doing for the last three years in the University of Guadalajara, Mexico.

A group of 100 dogs have been subjected to pneumonectomy and after the closure of the bronchus, we then covered the stump, applying freeze-preserved (−10°) superior vena cava which is sutured to the bronchial and peribronchial tissue using fine atraumatic 5-0 Deknatel sutures (separate or continuous stitches). Groups of dogs have been sacrificed from 48 to 6 months after operation.

(slide) This is a gross specimen of an animal sacrificed 15 days after operation. We see the firm consolidation of venous tissue over the bronchial wall.

(slide) This is a microscopic section of a dog sacrificed one month after operation. We see the intense fibrous reaction which covers bronchus and venous tissue.

(slide) This is a microscopic section of a bronchial specimen of a dog sacrificed 6 months after surgery. It is interesting to note that it is almost impossible to recognize venous tissue because of the great fibrous reaction. We believe that this strong reaction which appears very early after we cover the stump with vena cava helps a great deal in obtaining a firm closure of the bronchial stump after resection. Some of the veins have been kept for as long as 100 days before use, according to our special procedure.

During the last year and one-half, we have used this procedure in 24 human patients who were operated on at Zoquipan Hospital. In those patients, we used human superior vena cava. All were tuberculous patients subjected to upper lobectomies and pneumonectomies. One patient died fifteen days following right pneumonectomy. The autopsy showed as cause of death, cardiac failure. The bronchial stump showed a good fibrous recovery.

The remaining patients are now under good control.

DR. BELL (Closing).—I do not wish to leave the impression that all postresection reactivations in tuberculosis are necessarily associated with chronic occult fistulas. They may or may not be. In many instances, however, of postresection reactivation, their presence should be ruled out if possible. We have seen chronic occult fistulas without any evidence of tuberculous activity up to two or three years postoperatively. On the other hand, they may be associated with periodic hemoptysis or secondary infection, and may need treatment. Another point is that careful microscopic examination of tissues, removed at the primary resections in this group, did not show any evidence of unrecognized endobronchial disease. It is also of particular interest that a lobectomy was successful in arresting the disease when carried out at a level only a few millimeters lower than the level of the occult fistula segmental stump, yet we had no stump ulcers or fistulas of the lobe bronchus in the series.

# EXTRAPERIOSTEAL PLOMBAGE THORACOPLASTY: OPERATIVE TECHNIQUE AND RESULTS WITH 161 CASES WITH UNILATERAL SURGICAL PROBLEMS

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THE purpose of this paper is to record our experience with extraperiosteal plombage thoracoplasty in the treatment of patients with unilateral surgical problems. The application of this procedure to patients with bilateral surgical problems will be the subject of a subsequent report.

As indicated in Table I, a total of 161 extraperiosteal plombage thoracoplasties were performed for unilateral surgical problems between August, 1949, and June, 1954. Eighty-six operations were performed in two stages. The second stage consisted of resection of the previously deperiostealized ribs and the removal of the plombage material. The first rib and the transverse processes were preserved. The one-stage operation was used in 75 cases. Here the plombage material was left in place permanently. The techniques of these procedures will be illustrated and discussed later.

*Age.*—The age of the patients ranged from 16 to 66 years. Twenty-two per cent were over 50 years of age. Seven patients were over 60 years of age.

*Sputum Status.*—One hundred and thirteen patients (70 per cent) had a positive sputum. The majority of these (103) were positive by smear or concentration. Forty-eight patients had negative sputum preoperatively but 40 of these had definite cavity on the roentgenogram.

*Preoperative Roentgenogram.*—No cavity was visualized in 16 patients, 9 of whom had positive sputum. These cases represented largely those who previously had had extensive destructive lesions or recurrent disease. Honeycombing in the site of previously extensive disease was present in 4, 3 of whom had positive sputum. A definite cavity was present in 141 (88 per cent). The cavity size is listed in Table I. Note that most cavities were under 4 cm. in diameter. Extraperiosteal plombage thoracoplasty has not been used electively in the treatment of larger cavities.

Thus, only 8 (5 per cent) of the 161 patients had both a negative sputum and the absence of cavity on the roentgenogram. Ninety-five per cent of the patients had an open cavity and/or a positive sputum.

From the Surgical Service, Dr. U. E. Zambarano Memorial Hospital, Wallum Lake, R. I., and the Overholt Thoracic Clinic, Boston, Mass.
Read at the Thirty-sixth Annual Meeting of The American Association for Thoracic Surgery at Miami Beach, Fla., May 7 to 9, 1956.

TABLE I. EXTRAPERIOSTEAL PLOMBAGE THORACOPLASTY, AUGUST, 1949, TO JUNE, 1954

| | | | |
|---|---|---|---|
| Total = 161 | | | |
| Two-stage operation | | 86 | |
| One-stage operation | | 75 | |
| Age of Patients 16 to 66 years | | | |
| 16 to 20 years | | 4 | |
| 20 to 50 years | | 121 | |
| 50 to 60 years | | 29 | 22% |
| 60 to 66 years | | 7 | |
| Preoperative Sputum | | | |
| Positive on smear on concentrate | | 103 | 70% |
| Positive on culture or guinea pig inoculation | | 10 | |
| Negative | | 48 (40 had cavity) | |
| Preoperative Roentgenogram | | | |
| No cavity | | 16 | |
| Honeycombing | | 4 | |
| Cavity | | 141 | |
| 1 to 2 cm. | 57 | | |
| 2 to 4 cm. | 66 | | |
| 4 to 5 cm. | 14 | | |
| 5 to 8 cm. | 2 | | |
| 2 cavities | 2 | | |
| Preoperative Chemotherapy | | | |
| None | | 9 | 54% |
| Interrupted | | 78 | |
| Primary | | 74 (46%) | |
| Postoperative Chemotherapy | | | |
| None | | 31 (19%) | |
| Less than 3 months | | 36 (33%) | |
| Over 3 months | | 94 (58%) | |

*Preoperative Chemotherapy.*—Nine patients had no preoperative drug therapy. Seventy-eight had had either previous or interrupted courses of chemotherapy. Only 74 (46 per cent) were operated upon under the protection of a primary course of antimicrobial therapy.

*Postoperative Chemotherapy.*—Thirty-one patients had no chemotherapy in the immediate postoperative period, 36 had less than three months, and 94 (58 per cent) had over three months of drug therapy. Many of these patients, of course, had subsequent chemotherapy in an attempt to control persistently positive sputum or active disease and also for protection during subsequent resection.

## TECHNIQUE

*Two-Stage Operation.*—

*First stage* (Fig. 1): The incision is made and the thoracic cage exposed as for conventional thoracoplasty. The number and length of ribs stripped of their periosteum is likewise fashioned to collapse the cavity area adequately and collapse the uninvolved lung as little as possible just as in the case of a conventional thoracoplasty. The periosteum is stripped completely from all ribs from the second rib down. However, the periosteum is stripped only from the undersurface of the first rib. The periosteum and muscle attachments on the superior surface of the first rib are left intact. The gutter area is developed completely by stripping the periosteum to the heads of the ribs and

cutting the intercostal muscles. The intercostal vessels and nerves are not cut except for the first which is usually divided while doing a very modified apicolysis consisting of wiping the lung down from beneath the brachial plexus. A more extensive apicolysis is considered to be contraindicated in plombage thoracoplasty. When an extensive apicolysis is performed, the plombage material is no longer placed in the extraperiosteal space but into direct contact with all the mediastinal structures and lymphatics. It is our

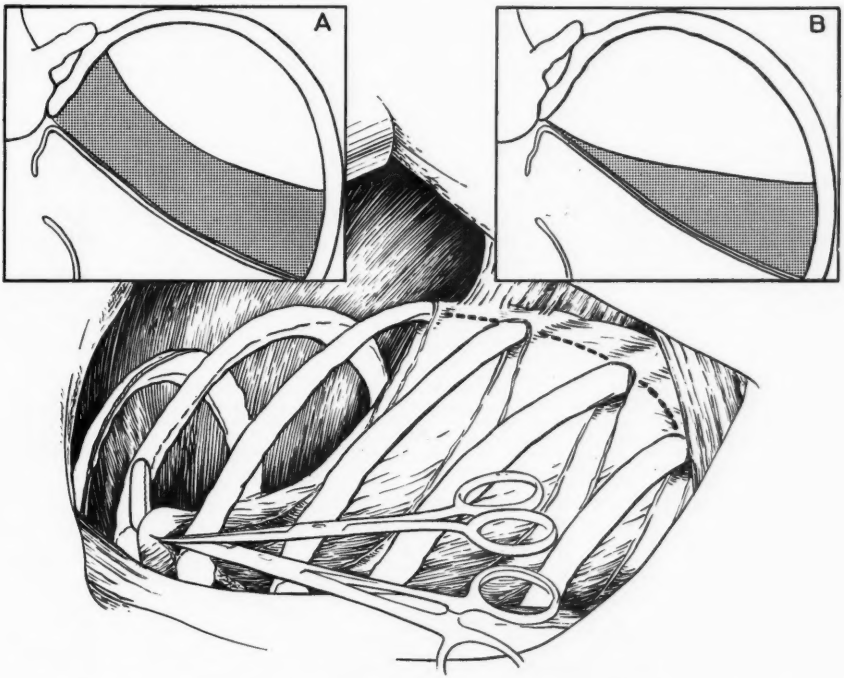



Fig. 1.—Illustration of the first stage extraperiosteal plombage thoracoplasty. The periosteum has been stripped from ribs 2 through 6 but only from the under surface of the first rib. After the periosteum has been stripped posteriorly to the heads of the ribs, the suspended intercostal muscles are cut as illustrated to prevent their suspension of the lung in the paravertebral gutter. If this is not done, the collapse in this important cavity bearing area will be inadequate (inset A) and the desired collapse (inset B) will be presented. Likewise, the intercostal muscles are cut anteriorly along the dotted lines to avoid their suspending action anteriorly.

In the case of a one-stage operation, a small strip of periosteum would be preserved on the outer surface of all ribs.

firm belief that this contributes to complications when using plombage material. The intercostal muscles are then cut anteriorly to avoid their suspending action. Two hundred thousand units of penicillin and 2 Gm. of streptomycin are placed in the extraperiosteal space which is now ready for the plombage material.

In our early experience, Lucite spheres alone were used. Later the spheres were placed in a polyethylene sheet. We now prefer to use a polyethylene

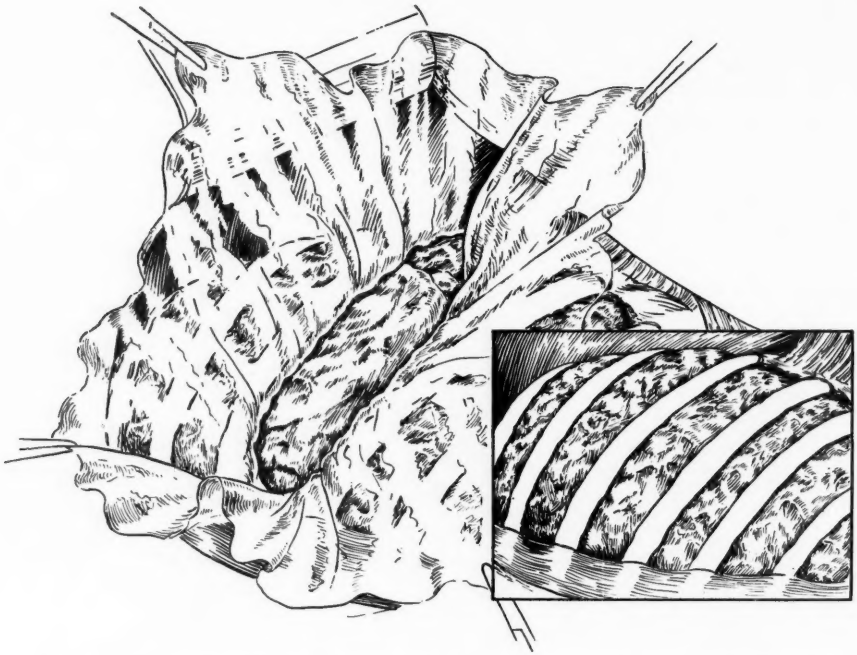


Fig. 2.—The first stage is being completed. The extraperiosteal space has been snugly filled with folded polyethylene sheets inside a polyethylene wrap. This maintains collapse and prevents paradoxical motion. Inset illustrates the final result after the lower fold of polyethylene has been placed under the upper fold which in turn has been brought down beneath the stripped ribs.

Fig. 3.—The second stage has been completed. The previously deperiostealized ribs have been resected. The first rib and transverse processes have been preserved.

sheet as a wrap and to use folded polyethylene sheets as a filler (Fig. 2). These create a smoother shelf, maintain the space very well, but are not so rigid as the spheres. Although we prefer the folded polyethylene sheets to Lucite spheres, our results to date have been equally good with both materials. The quantity of plombage material to use is just that which will snugly fill the extraperiosteal space and avoid creating pressure on the shelf. The wrapping is then closed around the plombage filler merely by passing the lower portion under the upper portion beneath the deperiostealized ribs. We have not found it necessary to seal the wrapping. The wound is then closed in layers.

*Second stage* (Fig. 3): The old scar in the skin is excised. The muscles are divided in the line of the previous incision. The deperiostealized ribs are resected from the transverse processes forward. The transverse processes with their attached ligaments and muscles and the first rib are left intact. This helps to avoid significant deformity although some scoliosis develops in every case. The plombage is removed and the number of the spheres or folded sheets of polyethylene are checked with the count recorded at the first-stage operation. A subtotal scapulectomy is performed only if indicated to prevent the scapula from riding on the costal cage. The wound is again closed in layers without drainage.

*One-stage operation:* This is performed in exactly the same way as the two-stage operation except for one detail. Since the ribs are to be left in permanently, a narrow strip of periosteum is preserved on the outer surface of the rib instead of stripping the rib bare of its periosteum. Our observations to date would lead us to believe that this helps to preserve the rib and prevent its degeneration as is frequently seen when all of the periosteum is removed.

## COMPLICATIONS

Table II lists complications encountered and is largely self-explanatory. Attention is called to the extremely low postoperative tuberculous complication rate (0.6 per cent). This one complication consisted of perforation and tuberculous infection of the extraperiosteal space. This went unrecognized until it was discovered five months later at the time of resection which was performed because of persistently positive sputum. The second stage of the thoracoplasty was performed at the time of resection and the extraperiosteal space placed on drainage with suction for four or five days. The wound has never manifested any signs of infection since then and the patient is clinically well with a negative sputum.

The only nontuberculous infection of the extraperiosteal space occurred in a patient with a marked skin allergy which prohibited the use of any of the antibiotics as well as the usual agents used in preparing the skin for operation. He has since had the plombage removed and the second stage performed with an excellent result.

The absence of postoperative spreads or exacerbations is attributed to two factors: drug preparation and coverage, and the lack of paradoxical motion.

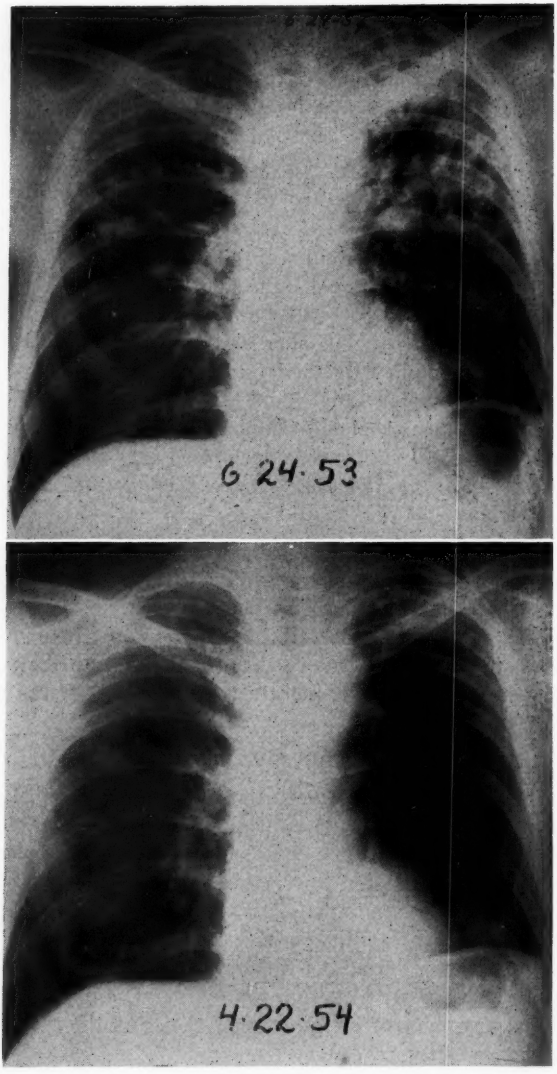
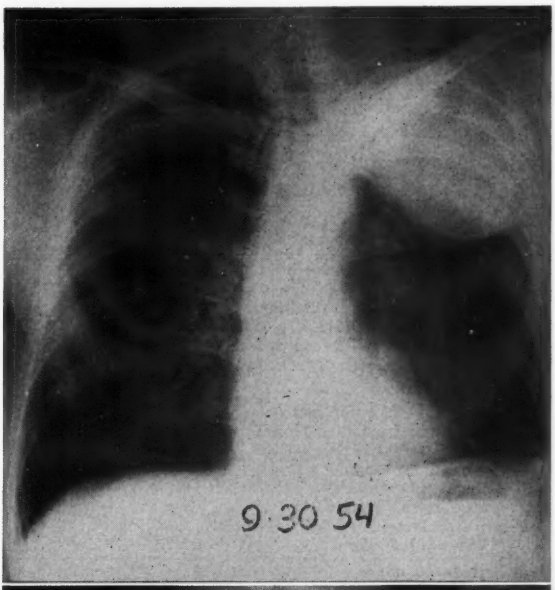
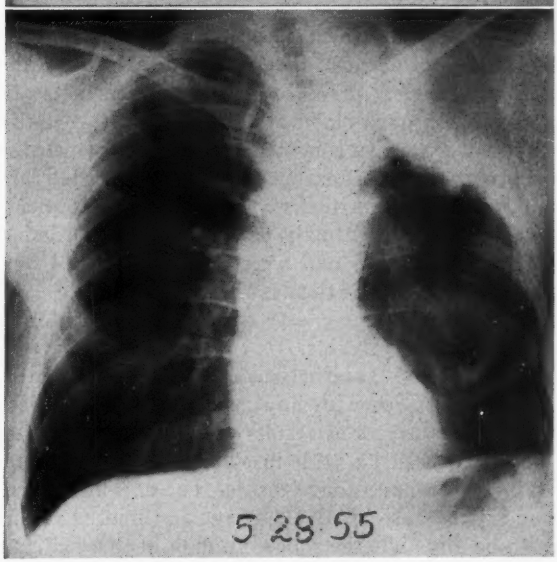



Fig. 4.—Two-stage extraperiosteal plombage thoracoplasty. *A*, Roentgenogram made at time of admission on June 24, 1953, revealing scattered infiltration throughout the upper half of the right lung and the entire left lung. A 4 cm. cavity is present in the left apex.

*B*, Roentgenogram of April 22, 1954, after ten months of antimicrobial therapy. A residual 3 cm. cavity persists in the left apex. The remainder of the disease has responded well to treatment. Sputum was negative.




*C.*




*D.*

Fig. 4.—*Cont'd. C,* Reontgenogram of Sept. 30, 1954, showing the polyethylene plombage in place. This was taken six months following the first stage and just before the second stage.

*D,* Roentgenogram of May 28, 1955—seven months following the second stage. Note the degree of scoliosis present. Also the preserved first rib and transverse processes.

*COMMENT:* This patient was a 38-year-old man. He has been well since his discharge from the sanatorium. He had no postoperative chemotherapy except for one week after the first stage. The second stage was performed after careful sputum studies revealed that the procedure had been successful. The vital capacity was reduced from 3,450 c.c. to 3,100 c.c. and the maximum breathing capacity from 110 to 98 L. per minute.

Today the surgeon no longer has to accept the patient with large quantities of sputum and with his tracheobronchial tree flooded with infected secretions. This probably is the dominant factor in preventing spreads. The absence of paradoxical motion afforded by the plombage also is an important factor. There can be no doubt that the effectiveness of the cough mechanism is greater and the interference with respiration is less following plombage thoracoplasty than following one of the conventional type.

TABLE II. COMPLICATIONS

| | |
|---|---|
| *Postoperative complications—3 (1.9%) | |
| Tuberculous—1 (0.6%) | |
| Perforation and infection of extraperiosteal space | |
| Nontuberculous—2 (1.2%) | |
| *Staphylococcus aureus* infection of extraperiosteal space | |
| Transient uremia | |
| Late complications | |
| Tuberculous—22 complications in 20 patients (12%) | |
| Ipsolateral exacerbation | 7 |
| Contralateral exacerbation | 11 |
| Wound infection | 2 |
| Renal tuberculosis | 1 |
| Ipsolateral spread | 1 |
| Nontuberculous—1 (0.6%) | |
| Wound infection | |

*Postoperative period—60 days.

Late tuberculous complications, especially contralateral exacerbation, has constituted the biggest problem in this group of patients. This has been our experience with any surgical procedure which is used in treating really significant tuberculosis. In our opinion, this is the result of the fact that many of these patients had extensive contralateral lesions preoperatively at the beginning of their treatment. All except one of the contralateral exacerbations occurred in an area of previous disease. Seven of the 11 patients with contralateral exacerbations were eventually controlled, 4 by antimicrobial therapy and 3 by further chemotherapy and resection. The other 4 were classified as having active tuberculosis at the time of this report in June, 1955. Since then, one has had a plombage thoracoplasty and one a segmental resection. The other 2 are considered to be salvable.

The low percentage of exacerbations on the side of operation has been in keeping with our experience with any type of permanent collapse therapy. Patients with initially successful results stand the test of time exceedingly well. Four of the 7 patients with ipsolateral exacerbations were resected with good results. Two have active disease, one of which is salvable and the other being hopeless because of advanced age and limited respiratory reserve. One is known to be alive but the follow-up data in this patient is inadequate.

The statistics on late complications include those of both the plombage thoracoplasty and all subsequent resections. The one ipsolateral spread and both wound infections occurred in patients who had subsequent resection, the first of these three complications occurring in a patient resected in another institution. These represent the only complications encountered in the 21 patients subjected to later resection.

Attention is again called to the fact that one half of the late complications occurred in the contralateral lung.

### DEATHS (Table III)

There were no postoperative deaths. This, plus the fact that tuberculous complications occurred in only one of the 161 patients, speaks for the safety of this procedure. This is especially significant when one considers that 95 per cent of the patients had either an open cavity, a positive sputum, or both. It is also significant when one considers that only 46 per cent of these patients were operated upon under the protection of their first course of antimicrobial therapy. These facts are in sharp contrast to most resection series in the literature which contain a high percentage of patients with closed lesions and negative sputum operated upon under the protection of their first course of chemotherapy.

The five late deaths were all due to nontuberculous causes. Three patients had sudden deaths caused by coronary occlusion. One patient died of metastases from a previously resected carcinoma of the breast. The other died of a severe undiagnosed enteritis in another hospital. Only one of the five late deaths occurred in a patient with uncontrolled tuberculosis at that time.

Not a single death has occurred in the postoperative period following either the plombage thoracoplasty or a subsequent resection. No deaths due to tuberculous infection have occurred early or late.

TABLE III. DEATHS

| | | |
|---|---|---|
| Postoperative deaths | | 0 |
| Late deaths | | 5 (3%) |
| Coronary occlusion | 3 | |
| Metastatic carcinoma | 1 | |
| Enteritis | 1 | |

### RESULTS (Table IV)

One hundred and thirty-two (82 per cent) of the 161 patients had completely satisfactory results with plombage thoracoplasty. Their sputa have remained negative and their clinical status satisfactory since the operation.

Twenty-nine (18 per cent) of the plombage thoracoplasties were considered to be failures. Of this group, 22 were considered to be initial failures, the patients' sputa never converting following operation. In one, the sputum remained positive for five months and then converted. In one, the sputum remained intermittently positive until the time of his death of coronary occlusion five and one-half years later. Another had one positive sputum by guinea pig inoculation eight months after operation and has been negative ever since. One remained positive for two years and then converted with further sanatorium care and chemotherapy. One has been clinically well since operation but his sputum has never converted. The remaining 17 have been subjected to resection—pneumonectomy in 2, lobectomy in 12, and seg-

mental resection in 3. Fifteen of the 17 had completely satisfactory results following resection. One patient, a drug addict, has been lost to follow-up. One has active contralateral disease.

Seven patients considered to have a successful result initially had a late exacerbation on the side of operation. Four of these were resected—one by pneumonectomy, one by lobectomy, and 2 by segmental resection. These 4 patients are all well. One of the remaining 3 has active disease but is considered to be salvable. One is considered to be hopeless because of her age (71) and limited respiratory reserve. One patient known to be alive and active refuses to answer our follow-up letter and, therefore, cannot be classified.

In summary, plombage thoracoplasty has been successful in controlling the lesion for which it was performed in 132 patients (82 per cent). It failed to do so in 29 patients (18 per cent). Of the latter group, 19 were salvaged by resection and 3 by further antimicrobial therapy. Thus the lesion for which operation was indicated was eventually controlled in 154 (95.6 per cent).

TABLE IV. RESULTS

| | | |
|---|---|---|
| Total cases | | 161 |
| Successes | | 132 (82%) |
| Failures | | 29 (18%) |
| a. Initial failures | 22 | |
| b. Failures due to exacerbations | 7 | |
| Control of the ipsolateral lesion | | |
| By plombage alone | 132 (82%) | |
| By later resection | 19 | 154 (95.6%) |
| By later chemotherapy | 3 | |

FOLLOW-UP (Table V)

In June, 1955, a follow-up study of the 161 patients was carried out. The follow-up period ranged from one year to five years and ten months; was over three years in 89 patients (55 per cent); and over two years in 132 (82 per cent).

Five (3 per cent) patients died in the late follow-up period—3 of coronary occlusion, one of metastatic carcinoma, and one of enteritis. One patient, the drug addict, has been lost to follow-up. The remaining 155 patients (96 per cent) are known to be alive and an accurate follow-up was available in 152.

TABLE V. FOLLOW-UP, JUNE, 1955

| | | | |
|---|---|---|---|
| Total 161 patients | | | |
| Dead | | 5 (3%) | |
| Lost to follow-up | | 1 | |
| Living—inadequate follow-up | | 3 | 96% |
| Living—adequate follow-up | | 152 | 96% |
| Clinically well—negative sputum | 145 | | |
| Clinically well—positive sputum | 1 | | |
| Active disease | 6 | | |
| Duration of follow-up period | | | |
| Longest | 5 years 10 months | | |
| Shortest | 1 year | | |
| over 5 years | 30 | | |
| 4 to 5 years | 26 | | |
| 3 to 4 years | 33 | | |
| 2 to 3 years | 43 | | |
| 1 to 2 years | 29 | | |

The classification of these 152 patients represents the opinion of the physician or clinic now caring for them. One hundred and forty-five patients were classified as clinically well with negative sputum. This group represents 90 per cent of the total 161 patients and 95 per cent of the living patients with an adequate follow-up. Of the remaining 7 patients, one is clinically well but has a positive sputum and 6 have active disease. All except one of these are considered to be salvable.

## DISCUSSION

Our experience with extraperiosteal plombage thoracoplasty began in August, 1949, after Woods, Walker, and Schmidt[1] had introduced the procedure to our clinic one year before. Our earlier cases were all of the two-stage type of operation. The original procedure of Woods, Walker, and Schmidt was modified by leaving the plombage in place for a minimum of two months and preserving the first rib and transverse processes at the second stage to avoid significant deformity. As our experience grew, we learned that the plombage material could be left in place for longer periods with safety. Eventually the second stage was delayed for four to eight months until the success or failure of the procedure in controlling the disease was established. If successful, the second stage was done. If unsuccessful, resection was performed and the second stage of the thoracoplasty completed at the same time. Thus, the patient's surgical treatment was accomplished with two operations regardless of the success or failure of the plombage. Subsequent resection in these cases has proved to be extremely safe and successful. In the 21 patients subjected to later resections, no postoperative deaths occurred and only one postoperative tuberculous complication took place. This was an ipsolateral spread following lobectomy performed in another institution. Nineteen of the 21 patients are now well. Plombage failures can be treated more easily and successfully than resection failures.

The first one-stage extraperiosteal plombage thoracoplasty was performed in November, 1951. A total of 75 are in this report. The longest follow-up is three and two-thirds years. Twenty have been followed for more than three years and 63 for more than two years. In the postoperative period, only one tuberculous and one nontuberculous infection of the space has occurred. These 2 cases have been described previously under complications. There have been no late infections of the space. Likewise, there has been no evidence clinically or by direct observation at operation of infection of the extraperiosteal space at the time of the second stage in the other 86 cases. In these cases the second stage was performed from two months to four and one-half years following the first stage. In addition, the fibrin and serum from the space have been studied in the last 21 consecutive cases: 14 by smear and culture; one by smear and guinea pig inoculation; and 6 by all three methods. These have all been negative.

The lack of late complications in the extraperiosteal space is attributed to three factors: one, the careful selection of patients; two, avoiding the use of the conventional type of apicolysis; and three, the type of plombage material used.

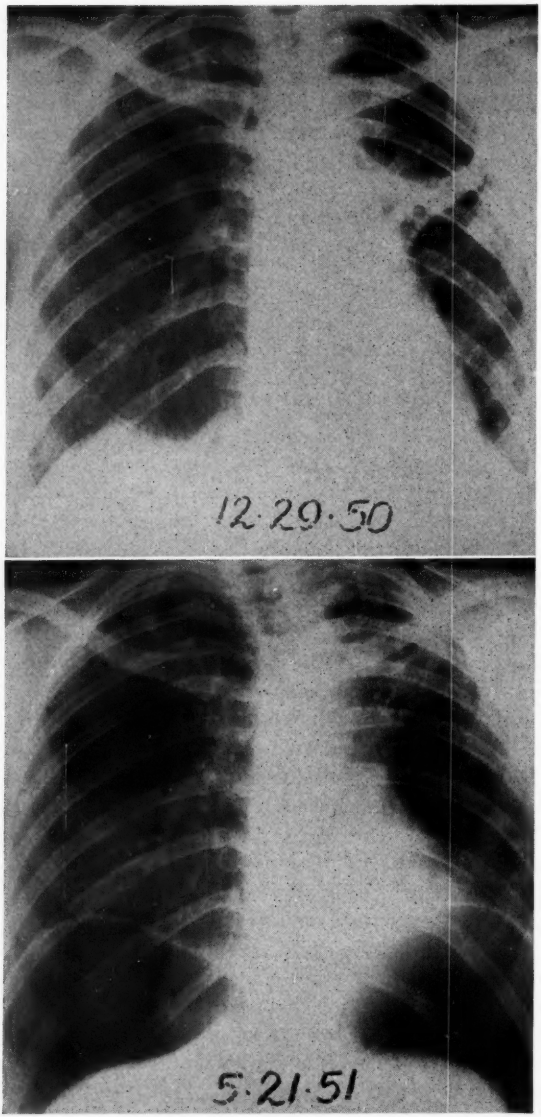
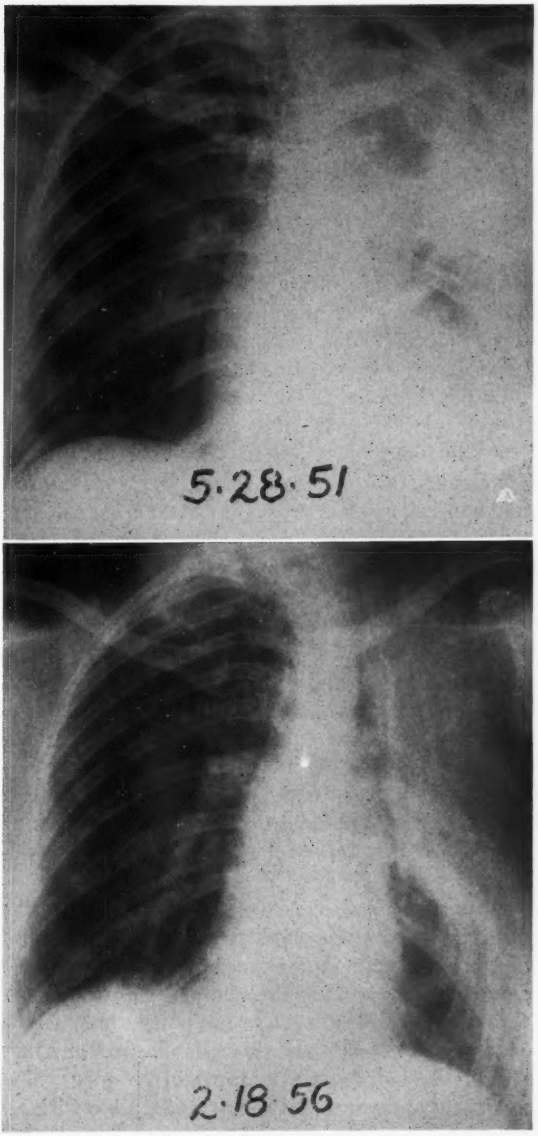



Fig. 5.—Below-up thoracoplasty with extrapleural mobilization of cavity. *A*, Roentgenogram of Dec. 29, 1950, showing widespread bilateral disease with a 4 cm. cavity in right upper lobe and a giant cavity in left upper lobe.

*B*, Preoperative oblique roentgenogram of May 21, 1951. The cavity in the right upper lobe is now closed. A giant cavity is still present in the left upper lobe. Note also the involvement of the superior segment of the left lower lobe and scattered nodulation throughout basal segments. The sputum was positive on smear.




*C.*

*D.*

Fig. 5.—*Cont'd. C,* Roentgenogram of May 28, 1951, just six days following lower stage of the thoracoplasty and mobilization of the cavity. Note the rapid decrease in size of cavity.

*D,* Roentgenogram of Feb. 18, 1956—four years and eight months following operation. Note that the transverse processes have been preserved.

*COMMENT:* This 25-year-old woman represented a serious problem. She had had extensive disease on the right side. Certainly no resection short of left upper lobectomy and resection of the superior segment of the left lower lobe could have been considered for the left side. A pneumonectomy might have been necessary if exploration had been performed because of the nodulation in the inferior segments. A below-up thoracoplasty under these circumstances is preferred by us over either of these resections.

This type of cavity is considered to be a contraindication to plombage thoracoplasty.

This patient has been well since operation. Her sputum converted in one month. She has since had two children and has been able to care for her family.

Plombage thoracoplasty is indicated in our scheme of therapy for cases with cavities of 4 cm. in diameter or smaller. Peripherally located, thin-walled cavities and larger cavities are considered to be contraindications. Such cases are treated either by resection or by staged thoracoplasty. Most of the staged thoracoplasties are performed from below up, with mobilization of the cavity area by extrapleural dissection at the time of the first and lower stage (Fig. 5).

The only apicolysis permitted with plombage thoracoplasty is the division of the first intercostal bundle and wiping the lung from behind the brachial plexus. A more extensive apicolysis is considered to be absolutely contraindicated because this places the plombage in direct contact with the mediastinal structures including its numerous lymphatic nodes and channels. In our opinion, this predisposes to infection of the space.

A satisfactory plombage material must be easily sterilized and easily removed from the extraperiosteal space at any time. Either Lucite spheres or polyethylene sheets inside a polyethylene wrapping meet these requirements admirably. They can be sterilized by soaking in aqueous Zephiran for twenty-four hours. They can be removed from the extraperiosteal space at any time, even a few years later, with great ease. The various sponges do not meet these fundamental requisites, in our opinion, and have not been used.

However, in spite of the lack of infectious complications in the extraperiosteal space thus far, much more time will be required before a final evaluation of this problem can be made. Every surgeon knows that the presence of a foreign body can lead to delayed infections several years later. Because of this one factor, this report regarding the one-stage plombage operation must be considered a preliminary one. With regard to the two-stage operation, however, we feel that we can state without hesitation that the plombage can be left in with safety for at least eight months. At the present time, it is our policy to perform the two-stage operation upon the younger patients and reserve the one-stage procedure for those over 45 years of age or for those with bilateral problems.

If there is no uncontrolled or threatening lesion other than the one for which thoracoplasty is being performed, chemotherapy is terminated one week following operation. Our experience has led us to believe that lesions controlled by permanent collapse stand the test of time exceedingly well without the aid of antimicrobial therapy. If chemotherapy is continued in the postoperative period, many of the failures are camouflaged, the sputum being negative even though the offending cavity may still be open. We prefer to discover the failures early and proceed as early as possible with resection in such cases. We have had no reason to regret this policy.

The advantages of plombage over the conventional staged thoracoplasty are self-evident. The surgical program is reduced to one or two operations even in the case of failures where the patients later require resection. In addition, the second stage is performed months rather than weeks following the first stage, providing the patient with more time for recuperation. The total collapse is accomplished at the first operation which brings about more rapid conversion of sputum. The two-stage operation results in a mild scoliosis but

no significant clinical deformity because of the preservation of the first rib and transverse processes. The one-stage operation produces no deformity. There is no postoperative paradoxical motion. This causes less disturbance in respiration and makes the cough mechanism more effective. As a result, the postoperative course of these patients is unusually smooth. It is rare to see retention of secretions or severe dyspnea even in the bad risk patients. The only special care required by these patients is the routine aspiration of the extraperiosteal space on the second day and as needed thereafter to avoid pressure. These patients recuperate faster and require less postoperative care than any group undergoing surgical treatment for pulmonary tuberculosis.

At a recent meeting of the New York Up-State thoracic surgeons, Gaensler[2] outlined four undesirable effects of operation upon pulmonary function: (1) interference with the negative intrapleural pressures; (2) pleural reaction; (3) paradoxical motion of the chest wall; and (4) unpredictable complications. Certainly, plombage thoracoplasty produces none of these undesirable effects. It does not interfere with the intrapleural pressures or produce pleural reaction unless the pleural cavity is entered as a result of a technical error. Paradoxical motion is avoided. Unpredictable complications are truly rare and are less a problem with plombage thoracoplasty than with any other procedure we have used. Plombage thoracoplasty stands out in sharp contrast with resection which produces all of these undesirable effects except paradoxical motion. This is a factor of extreme importance when treating patients with limited pulmonary function.

We have found the functional loss with this procedure to be relatively small and predictable. Forty patients have had ventilatory studies preoperatively and again postoperatively after three months. The average loss of vital capacity was 477 c.c. and the average loss of maximum breathing capacity was 17.4 L. The loss of maximum breathing capacity ranged from 0 to 10 in 57 per cent, 10 to 15 in 25 per cent, 15 to 20 in 10 per cent, and 20 to 32 L. in only 8 per cent.

Plombage thoracoplasty has several disadvantages. The difficulty with interpretation of the postoperative roentgenogram is disturbing. With the plombage in place, no type of examination by x-ray, including laminography, is of value. The underlying lung just cannot be visualized. In cases with persistently positive sputum, the other areas of the same lung and the contralateral lung must be evaluated in making decisions about further therapy. With present techniques, the migration of spheres or polyethylene packs is no problem. The two great disadvantages of the one-stage operation are the presence of a foreign body with its potential of erosion and infection and the fact that periosteum does not regenerate a significant amount of bone when in contact with the plombage material. To date, we have had very little trouble with erosion and infection but, as stated before, much more time will be required for the final evaluation of this factor. It has been surprising to find little or no regeneration of rib where the plombage material is in contact with the periosteum. The musculo-periosteal shelf becomes thickened but remains flaccid even a few years later.

It is quite evident that more time will be required before the one-stage plombage thoracoplasty can be recommended as a safe procedure because of the presence of the foreign body. However, the two-stage operation can be recommended at present as a safe and effective procedure with a small and predictable loss of function. It avoids the four undesirable effects upon pulmonary function outlined so well by Gaensler[2] and, for this reason, is particularly suited to the treatment of cases with limited pulmonary function.

This is a simple operative procedure. There can be no question that it is safer than resection in the hands of any surgeon when used in the treatment of cavitary disease. This is especially true in patients with cavitary disease with organisms partially to completely resistant to the antimicrobial agents. The high mortality and morbidity rates associated with resection in this type of case have been presented in admirable fashion by Bell[3] and Murphy.[4] Because plombage thoracoplasty does not involve the handling, incision, and suturing of infected lung tissue and bronchi, we consider it a procedure of choice in treating such patients. However, we would not like to convey the idea that this procedure is used only in the resistant cases. We have such faith in the effectiveness and lasting cure afforded by permanent collapse procedures that they are frequently used in preference to resection even in the better risk patients.

In the chemotherapy era, resection has rightfully become the most popular type of surgical treatment for pulmonary tuberculosis. The resection statistics in the literature, however, are misleading. They are loaded and diluted with a high percentage of closed lesions, wedge and subsegmental resections of extremely small lesions, and patients receiving their first course of drugs. When patients with persisting cavity and positive sputum after long-term antimicrobial therapy and patients with tubercle bacilli partially or completely resistant to the drugs are analyzed, the mortality and morbidity are truly significant.[3, 4] Likewise, the statistics dealing with pneumonectomy and resection exceeding a lobe are much less favorable than those with resection of a lobe or less.[4]

In the drug era, we have lost sight of the fact that collapse therapy procedures also have become safer and more effective. Indeed, most of the concepts expressed today focus attention on the preceding era when drugs were not available and case selection was less than ideal by necessity. There is too little recognition of the fact that permanent collapse is very effective and the successes stand the test of time exceedingly well. So long as the surgeon is called upon to treat not only the ideal case but also those with limited function and resistant organisms, collapse therapy must play an important role in the surgical program. In fact, unless collapse procedures are used, many patients will be denied treatment since resection is not applicable to all cases. If resection is used to the exclusion of all other procedures, some patients will be subjected to relatively dangerous operations when simple collapse procedures could have been used with great safety and with the expectation of success in a high percentage of cases.

SUMMARY

Experience and results with 86 two-stage and 75 one-stage extraperiosteal plombage thoracoplasties have been presented.

There were no postoperative deaths following this procedure or following 21 resections performed upon failures. Five late deaths resulted from nontuberculous causes. No deaths have resulted from tuberculous infection.

Tuberculous complications occurred in only one case (0.6 per cent) in the postoperative period. Late tuberculous complications developed in 12 per cent. One half of these were in the contralateral lung.

The lesion indicating surgery was controlled in 82 per cent by plombage thoracoplasty alone. Of 29 failures, 22 have been salvaged by resection and further chemotherapy.

Ninety per cent of the total 161 patients and 95 per cent of the 152 with an adequate follow-up are well.

These results have been accomplished in spite of the fact that 95 per cent of the patients had positive sputum and/or cavity on the preoperative roentgenogram and only 46 per cent were operated upon with the protection of an original course of chemotherapy.

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## Discussion

MR. WILLIAM P. CLELAND, London, England.—It is a great privilege to be here today and to be allowed to participate in your meeting. I last had the privilege of addressing your Association in 1951 at Atlantic City, when I mentioned my earlier experiences with plombage operations which I had performed up to that time. I think it is proper that those of us who have had a fairly lengthy experience with this operation should report our views from time to time, particularly as regards the long-term follow-up.

Dr. Wilson's presentation, I think, was an extremely admirable one and he brought out one or two very important and significant points. The first of these was that the plombage patients were significantly different from the majority of those considered suitable for resection. Of my own material (which now amounts to 340 personal cases) over a third were considered entirely unsuitable for any other form of surgical treatment. I think that is an important point, as Dr. Wilson rightly pointed out.

With regard to the future of this procedure, there are two points I should like to mention: (1) how does this procedure compare with the ordinary standard method of surgical collapse therapy, and (2) what is the incidence of complications related to the use of this sort of material?

(Slide) This represents the present number (340 operations) up to the end of 1955. You will see that 238, or 70 per cent, were regarded as satisfactory, a term used to cover a variety of things such as cavity closure, negative sputum, ability to work, and so forth.

These 238 patients were satisfactory without any additional treatment. Some 12 per cent required further treatment such as prolonged chemotherapy, conversion into a thoracoplasty or subsequent resections, before they were satisfactory. So that 82 per cent of this group are regarded now as satisfactory. Of the 6 unsatisfactory patients at the present time, there are 3 with persistent cavitation; 2 of those will probably be suitable eventually for resection, one is quite hopeless for any further treatment. There are quite a number, unfortunately, (17) that are untraced. Of those who have died (35), you will notice that only 4 died in the early postoperative period, that is, within a month or six weeks of operation, and 31 have died subsequently. This rather high incidence of later deaths is, I think, related to the type of patient we are treating, although 14 died from unrelated causes such as lung cancer and from coronary occlusion, while 17 died directly or indirectly from pulmonary tuberculosis.

(Slide) This is a comparison between plombage and the Semb type of thoracoplasty; these thoracoplasty figures represent operations carried out at a slightly earlier period than the plombage procedures and are not, therefore, strictly comparable, particularly in that the amount of streptomycin available and employed was probably very much less. But you will see that there is no appreciable difference between the two groups. I would not say that plombage is better, but neither is it significantly worse. One striking difference, however, is the difference in early mortality. There are 29 cases in the thoracoplasties compared with 4 with plombage, but the reverse is true with late mortality, namely, 15 for thoracoplasty and 31 for plombage.

(Slide) You will note we have had 18 patients (5.3 per cent) with space infection. I have regarded all cases except the obviously pyogenic ones as being tuberculous in origin whether or not we can find and culture tubercle bacilli. You will notice that most of them are in the early cases. The decrease in complications of this sort is due, I think, to the employment of very much more streptomycin, and also to improvement in technical procedures and to better selection of cases.

(Slide) This slide indicates the interval between operation and onset of infection. Most of these occur within the first two years of operation, but there is one rather disturbing group here which occurred four to six years after the procedure. That is the only feature of this operation which is a little bit worrying, that infection can occur quite late after the operation.

(Slide) One important feature about space infection, however, is that when it does occur it is not necessarily the end. Provided it is recognized reasonably early, it is a simple and straightforward matter to deal with, and should finish with a quite satisfactory final result. Of the early pyogenic infections, they have presented no real problem provided they are recognized and treated by removing the plomb and doing a thoracoplasty. Of the late tuberculous infections, 14 of the patients had a thoracoplasty and 11 of these healed by first intention; 3 had a sinus for some two or three months afterward. Five patients have subsequently died either from widespread tuberculous disease of the same or the opposite lung, or from unrelated causes, not necessarily related to the tuberculous infection. In one case, the plomb alone was removed without thoracoplasty, and one case was treated by aspirations and chemotherapy. Both have done well, but I do not recommend it as a routine measure. Two had nothing done; both were unrecognized at the time, and one of them developed amyloid disease and by the time he came back, it was quite impossible to help him.

It is always very important to try and determine the reasons for failure in any procedure and plombage is no exception. With regard to the failure of the operation to deal with the initial situation, that is, where there is persistence of cavitation, I believe that the most important single factor is the presence of bronchial disease. We have already heard a little bit about that and I think in the paper following this, we shall hear a great deal more about this very important factor. Of the cases we have resected after plombage, I think some 60 or 70 per cent have shown significant endobronchial tuberculous lesions which I am sure have contributed to the failure of the operation. With regard to space infection, I believe the most important single factor is the opening up and cutting through

of infected tissues and I would prefer not to use a plombage in any case where the apex of the lung is very adherent, where one is almost certainly cutting through infected lymphatics; I think under those circumstances it is much wiser to do a standard thoracoplasty. Another factor in the production of space infection is the presence of uncontrolled to inadequately controlled disease beneath the plombage, which was the case in about 50 per cent of our patients. I now make it a practice to carefully assess, by all means at my disposal, the condition of the lung beneath the plombage six months after the operation and, if things are not entirely satisfactory, then I proceed without delay to carry out a resection if such is practical.

DR. JOHN B. PETTER, Rutland Heights, Mass.—I appreciate the privilege of discussing Dr. Wilson's excellent paper, and would like to present briefly our experience at Rutland Heights Veterans Administration Hospital. Our operative technique is similar; however, we prefer the polyethylene spheres introduced by Lucas and Cleland in 1950. These have the advantage that they may be sterilized by boiling. We do not remove the spheres unless infection occurs. In the past four years we have restricted the use of plombage to the poor risk patients in whom we believed resection was contraindicated, due to the presence of drug-resistant organisms, advanced age, borderline functional reserve, or unfavorable disease distribution.

(Slide) We have performed 73 polyethylene ball plombages on 66 patients during the past four years. In the same period, 292 resections were done, a ratio of 4 to 1. Eleven patients were open negative at the time of surgery; 55 were open positive, of which 43 demonstrated drug resistance. Sixty-two patients had bilateral disease. In addition to the 7 patients who had bilateral plombage, 8 others had previous contralateral resection of thoracoplasty.

(Slide) The surgical complications were limited to two fistulas, seven space infections, and two postoperative bleeding problems. The space infections healed promptly on removal of the balls and overlying ribs.

(Slide) The effect of plombage on pulmonary function is of particular interest since many of these poor risk patients have a limited reserve. Although some patients exhibited a gain in maximum breathing capacity (MBC) and vital capacity, most had small losses with a mean loss of 11 L. MBC and 461 c.c. vital capacity. These losses are slightly smaller than the mean losses following resection of from three to five segments in uncomplicated cases.

(Slide) Of the 55 patients open-positive at the time of surgery, 29 or 53 per cent became closed-negative within eight months. Of the 26 remaining positive, 19 had late resections which were all well tolerated, with 17 promptly becoming negative.

(Slide) A one- to 4-year follow-up of these poor risk patients indicates that 57 are now closed-negative; 40 achieving this by plombage alone, 17 with additional late resection. Seven remained positive. There were no surgical deaths; there was one late tuberculous death from a fistula, and 2 nontuberculous deaths from hepatitis and carcinoma of the pharynx.

We agree that plombage is a safe procedure, particularly useful in increasing the salvage rate of the poor risk chemotherapy failures.

DR. PAUL DE CAMP, New Orleans, La.—I certainly have enjoyed these presentations and we, too, occasionally find patients in whom we are afraid to do resections. I would like to show a film of a procedure that we learned from Dr. Fernando Paulino in Brazil, which has been presented here before. In this procedure a conventionalized Semb type of apicolysis is performed and then, for collapse, very minimal foreign body material is used.

The apicolysis has been performed, the apex of the lung and overlying tissue is brought up and now a soft cotton ligature is placed around the involved lung and overlying tissues. The last one is placed around the lung and overlying tissues below the lowest point of significant palpable disease. At the present time we find we are using the procedure for very much the same kind of case that the extraperiosteal plombage is used for. These are patients who have resistant organisms and in whom a resection would be

either too extensive or too hazardous, so this procedure is performed. We use three or four of these ligatures. In this case, portions of the first, second, third, and fourth ribs have been removed; normally, we now leave in the first rib.

We have performed this operation about fifty times. In five instances, it has been done as a bilateral procedure for bilateral disease. The chief limitation of this operation technically is that it cannot be applied to disease below the hilum. However, there can be included in it the apical segment of the lower lobe. It can also be applied if one gets inside, planning to do a resection, and finds that the case is unsuitable for resection. If there is a majority of the disease as cavitary lesions above the hilum, these ligatures may be applied to the lung above the hilum. In our hands, in this series of 50 cases, we have had one intrapleural pyogenic infection and one subscapular space pyogenic infection. These responded to drainage alone. We have had no tuberculous infections either within or without the pleural cavity. I regret that others have not been so fortunate, and I wish I knew the reason why they have had difficulties so that I could tell you how to avoid them.

DR. ELLIOTT MICHELSON, Baltimore, Md.—I should like to congratulate Dr. Norman Wilson and also Mr. Cleland on their excellent results with the extraperiosteal Lucite plombage thoracoplasty, a procedure which may well supplant the standard thoracoplasty. In line with the Presidential Address by Dr. Meade yesterday on the "Forgotten Men in Thoracic Surgery," it is interesting to note that Dr. Oughterson and Dr. Harvey in 1930 suggested the extraperiosteal space filling as a method of lung collapse therapy. They used a rubber bag, infection developed, and they were discouraged from further use of the procedure. Since that time a great number of surgeons have placed diverse materials in this space, including air, fat, muscle, paraffin, and plastics of all kinds. At Sunmount Veterans Hospital, in 1948, we were interested in some type of collapse procedure for patients with borderline ventilatory function and bronchospasm. The temporary Lucite plombage thoracoplasty operation was therefore developed. At the first operation maximum collapse is obtained by the Lucite spheres in the extraperiosteal space, and six weeks later the ribs and spheres are removed. During 1948 and 1950, 25 patients with maximum breathing capacity ranging from 20 to 40 L. per minute received this procedure with no mortality aside from one death from meningoencephalitis. Function test by Dr. George Wright revealed minimal loss of ventilatory function. The final results were similar to those of Dr. Wilson and Mr. Cleland. I should like to emphasize that this operation should be the procedure of choice in patients with diminished ventilatory function since there is no paradoxical motion in the immediate postoperative period, adequate cough is possible, pulmonary function is preserved, and no chest or spine deformity develops. Whether the plombage should be removed at a second operation depends upon the surgeon's consideration of the calculated 2 to 5 per cent risk of tuberculous infection in the extraperiosteal space.

DR. FELIX A. HUGHES, Memphis, Tenn.—We too have had a limited experience with plombage thoracoplasty. I reviewed our figures for the past three years and found that we have performed 188 plombage procedures on 153 patients during that time; 66 other types of thoracoplasty have been employed of which only 14 were the regular modern type of thoracoplasty. During the same period, 130 pulmonary resections were performed. I think the reason the plombage procedures exceeded the resections was that there had been an accumulation of cases of bilateral pulmonary tuberculosis that we had not considered to be suitable for resection. Many of the points I wanted to make have been adequately covered; for example, the maximal preservation of pulmonary function and a very low operative mortality—we had one death following 188 procedures.

We were at first very skeptical about plombage since a foreign body is introduced into the thoracoplasty space. Our early results were so good, however, that we thought we should not deny this procedure to many patients who have such extensive disease that no one would do a resection. We have therefore extended the indications for its use to many bilateral cases with cavities on both sides. As you know, the results obtained in

any surgical procedure for tuberculosis will depend in the main on the type of patients that are started with. So we did not anticipate a conversion of sputum of 85 to 90 per cent in this type of patient. In cases of a minimal lesion we have obtained around 85 to 90 per cent conversion. One other point is that resection is the best form of treatment if it is applicable. The plombage thoracoplasty has served to round out the surgical therapy of cases seen at Kennedy VA Hospital.

DR. EDWARD A. GAENSLER, Brookline, Mass.—I should like to congratulate Dr. Wilson on his outstanding results and also on his courage to continue a program of surgery which runs counter to prevailing trends. At the Sanatorium Division of the Boston City Hospital on Dr. Strieder's service, we also started plombage in the fall of 1949 and to date have performed 150 operations on 131 patients. Our patients also, for the most part, have been in the older age group, nearly all sputum positive, drug resistant, and with far-advanced disease. Our results also have been good, although not as outstanding as Dr. Wilson's, because a large number of bilateral cases were included, and because the selection for this procedure was often made by exclusion; no one dared to do a resection. There have been only two deaths in 150 operations, in spite of our training program where many plombages were the first or second experience for the particular surgeon.

Unlike Dr. Wilson, we have removed the plomb whenever possible at the end of four months. This was, first, because we originally used a reactive plomb, namely, Lucite spheres within a rubber glove; second, because of an early visit to our hospital by Mr. Cleland, who told us of his incidence of 5 to 10 per cent late infections; and third, because of the findings in our patients by Drs. Desforges, Gibbons, and Strieder, that a positive culture could be obtained from the subcostal space in 38 per cent of our patients, four months postoperatively (J. Thoracic Surg. **28**: 636, 1954). That this policy of conversion has been justified is borne out by our figures. There have been no subcostal empyemas in over 120 cases where the plomb was removed as scheduled. In patients in whom for some reason or other we could not remove the plomb, the incidence of subcostal tuberculous infection and empyema has been 15 per cent.

I feel that subcostal plombage should be considered as an important alternative to resection, particularly because we will see more and more older patients with far-advanced disease, resistant to all drugs, and with complicating "compensatory" emphysema. In these patients, subcostal plombage can be performed with a lower mortality, without the complication of bronchopleural fistula, and also with less loss of function, because in these patients the disease is usually distributed regionally rather than segmentally.

DR. ROBERT FOX, Chicago, Ill.—At the Municipal Tuberculosis Sanitarium in Chicago we have been using a modified thoracoplasty with extraperiosteal plombage since late 1950; first at the instigation of Dr. William Adams in Chicago and with gradual modification over a period of years. Since we started this procedure we have completed about 664 thoracoplasties with plombage, at least 25 with bilateral plombage. I should like to present some of our results in operations done before 1955, giving us at least a 15-month follow-up, inasmuch as we reviewed our figures just this last month. This totals some 531 thoracoplasties with plombage. For purposes of study we have divided these patients into three categories arbitrarily; the first group, those in whom we thought thoracoplasty would be a definitive procedure in that we had an excellent chance of getting the patient well; in many of these we felt resection was contraindicated. The second group are those in whom there was large cavitation, or because of the location of the cavity, we thought thoracoplasty had less than a 50 per cent chance of doing the job and yet wanted to do something to help the patient; and the third group, those in whom we thought we had practically a zero chance, patients with extensive disease, and yet we wished to help if possible.

(Slide) So far as complications and mortality were concerned, there were five deaths within three months of the time of operation, or just under 1 per cent. As Dr. Wilson indicated, some of these patients are old and many have rather poor respiratory reserve.

There were 26 late deaths or 5 per cent, and about one half were from nontuberculous causes. So far as postoperative atelectasis and spread or exacerbation elsewhere, there were 5 of these or just under 1 per cent; all responded to treatment.

(Slide) So far as the plomb material itself, or as Dr. O'Brien said some years ago, the "garbage" put into the extroperitoneal space; there were 46 patients or about 8.5 per cent who had sufficient subscapular fluid to necessitate one or more aspirations. There was only one early infection, and by early I mean within three months of operation. There were three late infections; in none of these did we get tubercle bacilli—they were all pyogenic infections; all responded promptly to removal of the pack. There were 82 who had sufficient migration of the wax into the soft tissue to necessitate removal of the pack. All these healed by first intention.

(Slide) Our results are as follows:

Group I.—274 cases, 91 per cent are alive and well today.
Group II.—220 cases, 74 per cent are alive and well.
Group III. (salvage)—57 cases, 25 per cent are alive and well.

We believe these figures speak for themselves, and we urge strongly that thoracoplasty be used in those patients in whom resection carries an increased risk of complication or failure.

DR. FRANCIS PHILLIPS, Bartlett, Alaska.—We also became interested in this type of procedure at the Seward Sanatorium, after seeing the work of Dr. Adams and Dr. Lee in Chicago in 1952. We have done only 150 cases. Of that number there were 12 in which we had some form of complication. In the early cases, in my enthusiasm with the wax I added a little more than I had prepared space for. When cicatrization had finally occurred, after several months a little outcropping of the wax occurred in the incision. This complication was simply remedied under local anesthesia. We had one case in which the wax was removed early because of a massive infection. This patient developed a *Streptococcus viridans* hemolytic bacteremia in spite of being heavily treated with antibiotics at the time. However, he is well today with a negative sputum and is working as a shoemaker.

There are three points in these procedures that I would like to discuss. This is a procedure that we now do under local anesthesia. It takes an hour to an hour and a half. The patient is up and walking around in the evening, after operation in the morning, with little suffering. I think this is important. Another point that I am beginning to think is important is the ease of the procedure for the surgeon. Those of you who are backed up by great universities with magnificent anesthesiology departments and skilled anesthesiologists have nothing to worry about. But in Alaska, I have to choose procedures that are easy to do and which spare the patient's life in the operative procedure itself. Also, in Alaska it has been calculated that it is costing us, in terms of *arresting* the disease, and I think that is the only category in which we can talk about tuberculosis (I think it is time we quit talking about the cost per day, and face it as the cost of arresting the disease), it is costing us, including social welfare, transportation and all incidental expenses, from $15,000 to $17,000 a case. That is under the old regimen. Now, with this operation, it is not unusual for us to get a patient into the sanatorium who will be there from one to three weeks, have the operation, and when he is going to a community where outpatient treatment is available, he will be discharged in four to six weeks to outpatient care. This is a tremendous saving in the cost of the treatment. This also can be measured in terms of hospital costs. It is much cheaper to do an operation that does not require the use of blood and a lot of extra nursing care. These patients have a minimum of postoperative complications. They require no special nursing care and the surgery is easier for the patient generally.

DR. WILSON (Closing).—When one expects to have his head chopped off, it is comforting to find that so many others are doing the plombage procedure with good results. I should like to re-emphasize that we are talking about unilateral surgical problems, and

that the majority of our cases had cavities of 4 cm. or less in diameter. I realize that Dr. Strieder, Dr. Gaensler, and their associates have used this procedure in patients with more extensive disease. I believe that this must account for the difference in our experience with infections in the extraperiosteal space. However, after they reported their experiences, we studied cultures from the spaces in many cases anywhere from two months to four and one-half years following the first stage and have been unable to find a single positive culture or guinea pig infection.

We also recognize the potential dangers of the foreign body, and for this reason perform a two-stage operation with removal of the plombage material in the younger, good-risk patients. The plomb is left in place in the older patients, in those with low pulmonary reserves and in those with bilateral problems.

We feel that permanent collapse is capable in itself of giving permanent control of a lesion if an initial success is accomplished. For this reason we prefer to use antimicrobial therapy only for one week following operation unless there is a contralateral lesion of significance that requires drug therapy. This enables us to discover the failures early and proceed with resection at an early date.

Finally, we should like to emphasize that good results with this or any other procedure will not be accomplished if it is used only as a salvage procedure.

# BRONCHOGRAPHIC STUDIES AS A GUIDE TO THE SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS

F. J. PHILLIPS, M.D.,* ANTHONY LALLI, M.D.** (BY INVITATION), AND WALTHER BUHLER, M.D.*** (BY INVITATION)
BARTLETT, ALASKA

THE purpose of this presentation is to emphasize the importance and diagnostic value of bronchography in the surgical treatment of pulmonary tuberculosis. The average case of pulmonary tuberculosis is no longer a treatment problem with our present antimicrobials and improved sanatorium armamentarium. However, the unknown pathologic ravages of the inadequately treated cases and the so-called old chronic cases are many fold and frequently unexplored. At the Seward Sanatorium, it has been found expedient to do bronchography almost routinely in all cases before any type of surgical treatment is initiated. The current, frequent finding of active tuberculous foci in resected specimens in patients with consistently negative sputums and the finding of active foci of tuberculosis in lungs apparently clear to x-ray studies as reported by Logan,[1] add additional importance to more intensive diagnostic bacteriologic and roentgenologic study. Buckles and associates,[2] from the Franklin Sanatorium, published a most impressive study on the value of bronchography including the pathogenesis of certain types of bronchiectatic lesions. Our studies are similar but lack the pathologic study of resected specimens. The problem of tuberculosis in Alaska has been so overwhelming that only recently have we been able to initiate studies evaluating our treatment efforts. We have no resident pathologist in all Alaska in civilian practice.

At the Seward Sanatorium, all patients are routinely bronchoscoped soon after admission. In skilled hands, bronchoscopy is a harmless procedure and frequently uncovers unsuspected problem lesions early in the management routine. Likewise, bronchography is employed freely as a diagnostic procedure. Normally, patients scheduled for bronchography are first bronchoscoped in order to effect bronchial cleansing. In addition to ordinary bronchial aspiration, a 2 per cent solution of ephedrine sulfate in saline as a mucosal astringent or medical bronchial dilator agent is injected through the bronchoscope and the bronchi leisurely cleaned by aspiration. The bronchi are routinely mapped out under fluoroscopic observation as illustrated and discussed in Di Rienzo's *Radiologic Exploration of The Bronchus.*[3] This is

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signally important since many irregularities that appear in the dynamic action of breathing are not manifest in the static film. Iodochlorol is used as the contrast medium injected through an ordinary rubber urethral catheter which is inserted through the bronchoscope at the time of the bronchoscopic aspiration. Lipiodol has also been used but there is no difference in the results and the Iodochlorol is more economical. Except in cases of obstructive bronchitis, the radiopaque material is almost completely disgorged in a few days. We have had no complications from its use. All patients except very young children are bronchoscoped under topical anesthesia. We use 2.5 per cent cocaine routinely in a quantity sufficient to produce good anesthesia; usually 4 to 6 c.c. Our native patients are unusually cooperative in all these procedures. Patients are preoperatively sedated with appropriate doses of Nembutal and codeine sulfate. Liquid nourishment is permitted up to one hour previous to the examination.

In the past seven consecutive years, 276 such bronchograms have been made, of which, 240 were in patients of known tuberculosis.* There were 112 males and 128 females in this study. There were 69, or 28.8 per cent, with bilateral lung involvement of some degree of bronchiectasis. Involvement in one lung only was found in 94 cases, or 34.1 per cent. There were 77 in the series without morphologic evidence of bronchiectasis. Hence, of the cases studied, 66.9 per cent had bronchiectasis in some recognizable degree. Since any significant amount of bronchiectasis may reasonably categorize a tuberculous patient as a candidate for resection, we have not further classified the cases as to type of bronchiectasis in this discussion. The type varied from cylindrical to large pendulous sacs.

There were only 29 cases in the series with obvious lower lobe involvement. Finding the bronchiectasis mainly in the upper lobes was initially a surprising observation, but apparently this is not unusual in pulmonary tuberculosis and well may have some significance in the etiology of the disease. On the basis of bronchoscopic observations, we have made a tentative division of the cases into 2 groups: Group 1, those without visible evidence of stenotic bronchitis and Group 2, those with such evidence. There were only 9 cases in Group 1. These 9 cases have bronchograms similar to W. E. (Fig. 1, *1*). This Eskimo girl came from a large family all of whom have had tuberculosis. Because of tuberculosis mortality in the family and geographic distances in Alaska, all members of the family have not been bronchographically studied. However, a brother and a sister, now alive with minimal arrested tuberculosis, did not have evidence of bronchiectasis. Hence, the apparent cystic disease in W. E. is probably not a familial characteristic.

Confluent active tuberculous involvement of the bronchi is seldom observed in our patients. In over a thousand bronchoscopic examinations, ulcerative lesions have been noted in only 2 patients. Scarring of the bronchial mucosa has been observed in many patients. In the absence of ectasia of the more distal bronchial divisions, this has not been a serious treatment

*We are indebted to Dr. Frank Maresh for the studies done in 1949 at the Seward Sanatorium.

problem either in the medical management or in the postoperative vigil following thoracoplasty or resection. We have not been able to relate this finding to the course of the disease except that our cases are predominantly

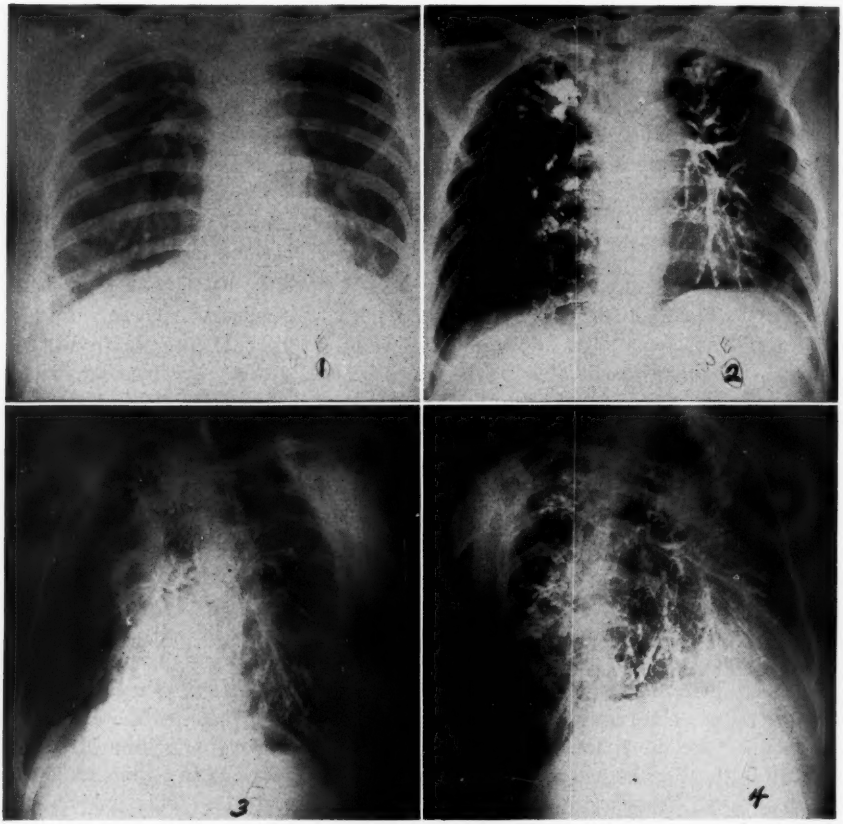

Fig. 1.—Case 1, W. E. *1*, Posteroanterior 72-inch film before bronchogram. *2*, Anteroposterior 30-inch film. *3* and *4*, Opposite oblique 72-inch films.

chronic because the general hospitalization program has been grossly inadequate for the number of people afflicted. Until recently there has been a long waiting period before hospitalization. It would appear that the patients had either died or developed a favorable resistance to their disease through their own immunologic potential.

## CASE REPORTS

CASE 1.—W. E., aged 29, full Eskimo. This case presents a serious treatment problem. In our judgment, surgical resection is indicated on the basis of the ectasia, but untenable because of the existence of the extensiveness of the involvement. Although she is ambulatory and has a sputum negative for acid-fast bacilli in repeated concentrate and culture

studies, a slight cold has normally made her an invalid for many days. She is then obviously dyspneic to the extent of cyanosis on exertion without obvious evidence of pneumonic changes in x-ray studies at the time. She is being kept on an expectant antibiotic treatment basis as a client in the vocational training division of the Sanatorium, but not as a Sanatorium patient.

CASE 2.—A. W., aged 24. This patient had a negative sputum on admission probably resultant from outpatient antimicrobial treatment while waiting for hospitalization. At the initial bronchoscopic examination, bronchography was included because of the suspicious

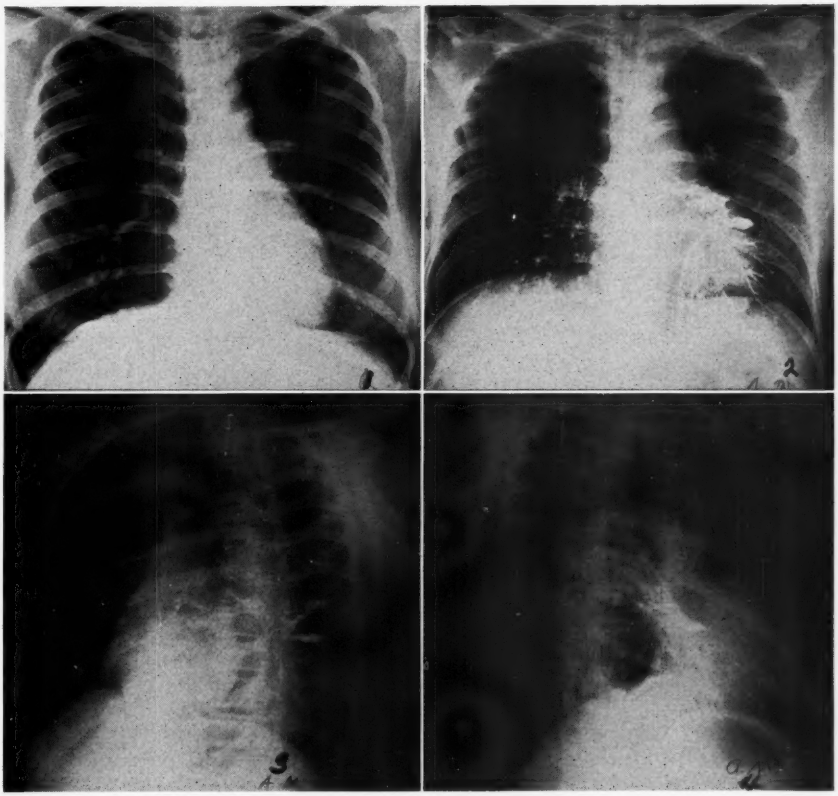

Fig. 2.—Case 2. A. W. *1*, Posteroanterior 72-inch film before bronchogram. *2*, Anteroposterior 30-inch film. *3* and *4*, Opposite oblique 72-inch films.

shadows in the right lower lobe area. However, bronchography revealed bronchial obstruction in the left upper lobe and ectasia in the superior segment of the lower lobe. There was old confluent scarring of the left main-stem bronchus without stenosis which we interpreted as old confluent healed tuberculous bronchitis. Left upper lobectomy and segmental resection were done two months ago. The sputum has continued negative. This case dramatically demonstrates the treatment evaluation importance of bronchography. Without the bronchogram, she would likely have been discharged lacking the surgical treatment only to be readmitted at a later date with more extensive ectasia.

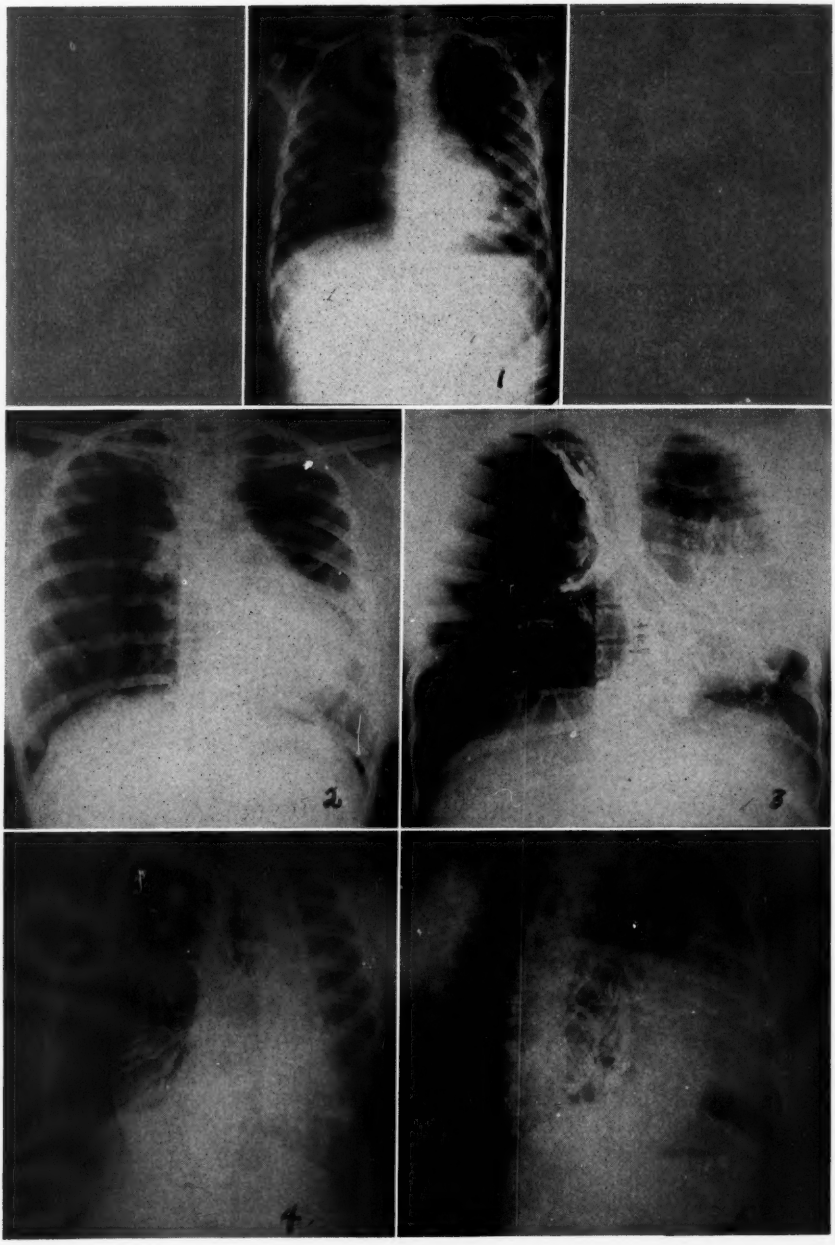

Fig. 3.—Case 3, L. J. *1*, Posteroanterior 72-inch film, 1949. *2*, Posteroanterior 72-inch film before bronchogram. *3*, Anteroposterior 30-inch film. *4* and *5*, Opposite oblique 72-inch films.

CASE 3.—L. J., aged 14, Alaskan Indian. This girl has been hospitalized since 1949 or since age 7. Fig. 3, *1*, although a poor film, reveals no disease eight years ago. Serial x-rays reveal progressive extensive bilateral involvement that defied all treatment procedures. Bronchoscopic examinations revealed confluent scarring of the right upper lobe bronchus, but no stenosis. The left lower lobe was similar. The bronchograms support this observation. Both the right upper and the left lower lobes are obviously of no respiratory value to her. Resection of the left lower lobe was done two months ago. Her postoperative course was uneventful. Right upper lobectomy is still to be done. The sputum is and has been negative to concentrate and culture for two years.

## DISCUSSION

These cases are representative of the types of lesions frequently found in Alaskan patients when adequately studied. They are very informative examples of the value of bronchography. Although, in cases of bronchiectasis of nontuberculous type we are conservative in doing surgical resection, we believe that these patients who have once had a sputum positive for acid-fast bacilli should have the advantage of resection of the involved areas if feasible from the respiratory reserve evaluation. Also, many of our patients return to remote areas where they may be visited by itinerant nurses only as often as every three to six months. Certainly, in the light of studies indicating the questionable arrest of cases even though sputum studies are negative, it is advisable to do resections when the indications are present as discussed in this presentation.

## CONCLUSIONS

1. Bronchography is a desirable procedure in the determination of the proper treatment to be followed in pulmonary tuberculosis.

2. Bronchography is a relatively innocuous procedure in careful, skilled hands.

3. Photographs of x-ray films demonstrating informative bronchography in pulmonary lesions are included with case comments.

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## DISCUSSION

DR. JOHN W. BELL, Sunmount, N. Y.—I wish to compliment Dr. Phillips on these excellent results in the face of considerable economic handicaps with this group of patients in Alaska. I would like to emphasize the great value of bronchography preoperatively in planning the extent of pulmonary resection. We can get an estimate of the probability of doing some type of resection from preoperative x-rays, but actually knowing whether you are going to have to do more than an upper lobectomy, say, including the middle or superior segment of the lower lobe, often can be determined only at operation and sometimes even that is difficult.

(slide) In this instance, we had considered doing a left upper lobe procedure, either a segmental resection or a left upper lobectomy for a 2 or 3 cm. cavity in this area. How-

ever, bronchography demonstrated crowding and clubbing of the left lower lobe bronchi. We believed that a pneumonectomy would probably be necessary and that the patient would not tolerate resection well because he had contralateral cavitary disease and limited respiratory function.

(slide) This is a preoperative bronchogram. A right upper lobectomy was carried out in this patient. You can see the unrecognized ectasia of the lower lobe existing at that time.

(slide) This same patient, a young Negro, came back eighteen months later with this bronchogram. The basilar segmental bronchi were so-called "sacs of pus." This was a nontuberculous secondary infection of a pre-existing bronchiectasis. We completed a pneumonectomy on this side.

DR. RICHARD H. MEADE, Grand Rapids, Mich.—While I was in Paris last June, Dr. Mathey took me to a tuberculosis sanitarium where he carried on his work, and I was very much interested in the radiology laboratory. Not only were they doing bronchograms on all patients before deciding on resection, but they were combining tomography with bronchography. Another point I think is worth mentioning. Dr. Bell mentioned that he used Dionosil. While I was in Davos, Switzerland, last summer, I had the pleasure of visiting Dr. Iselin, and he showed me the beautiful bronchograms that he had made with the use of Dionosil. I attempted to use it myself on my return but got into great difficulty. Then an article appeared in *Diseases of the Chest* on this subject, in which nothing was said about the preparation of the Dionosil. To those who know how to use it, what I say is superfluous, but for those who do not know, if you don't heat the syringe and if you don't heat the Dionosil, it is just like trying to inject barium sulfate.

DR. F. J. PHILLIPS (Closing).—Thank you very much, Dr. Bell and Dr. Meade, for your encouraging comments. We have not tried Dionosil, mainly because we have had such good success with Iodochlorol, and because of the difficulties in getting the material. Economy is something to be considered up there where we have not too much money. I am encouraged that so many people are so enthusiastic about bronchograms, and I would like to say that I think what has held up bronchography more than anything is the old wives' tale that we all heard many years ago, that if you dared to get iodine near a patient with tuberculosis he would automatically get a fulminating spread. Obviously, this is not true.

# ESOPHAGEAL EXCLUSION FOR PERSISTENT FISTULA FOLLOWING SPONTANEOUS RUPTURE OF THE ESOPHAGUS

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SPONTANEOUS rupture of the esophagus was almost uniformly fatal from the time it was first described by Boerhaave in 1724 until Eliason and Welty[1] reviewed the literature in 1946. However, during the past ten years many patients have been treated successfully and there has been increasing interest in this subject. It is now quite widely recognized that an early diagnosis of spontaneous rupture of the esophagus can usually be made, even though the symptoms are very similar to those of other serious conditions which occur much more commonly, and that immediate thoracotomy with closure of the esophageal perforation and adequate drainage of the chest is the treatment of choice.

The clinical picture is one of acute severe pain in the retrosternal area and perhaps epigastrium which often is secondary to vomiting following a large meal or drinking spree. The diagnosis is apt to be confused with coronary occlusion, a dissecting aneurysm of the aorta, or a perforated peptic ulcer below the diaphragm. The patient's clinical picture is one of a major catastrophe. The diagnosis of spontaneous perforation of the esophagus is usually confirmed by an x-ray examination. Mediastinal emphysema or air or fluid in the pleural cavity should substantiate the diagnosis. The most common mistake made is probably arriving at a diagnosis of acute coronary occlusion and deciding that the patient is too sick to have an x-ray examination, the correct diagnosis being made only after subcutaneous emphysema appears in the neck or at autopsy.

If empyema develops following spontaneous rupture of the esophagus, either because the defect is not sutured or because the suture line breaks down, some patients can be treated successfully by providing adequate drainage of the lower portion of the thoracic cavity. The fistula seals over and the drainage tract is obliterated in a manner similar to that following traumatic perforation of the cervical esophagus. Persistence of an esophageal fistula in the cervical area is rare and has not occurred in our experience. In the thorax, on the other hand, particularly following spontaneous perforation of the esophagus, a fistula may persist in spite of apparently adequate drainage and the application of suction.

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The purpose of this paper is to call attention to the principle of exclusion from the intestinal tract of that portion of the esophagus involved, as a means of overcoming the mediastinal and pleural infection. Three patients are reported who had a persistent fistula following spontaneous rupture of the esophagus. The first patient died in spite of the fact that apparently adequate drainage of the chest was provided. The second and third patients appeared to be running the same downhill course despite apparently adequate drainage. The thoracic esophagus was excluded from the stomach and cervical esophagus. This appears to have been a lifesaving measure for both patients.

## CASE REPORTS

CASE 1.—M. L., aged 59, was operated upon in another hospital on Jan. 14, 1954, because of severe acute symptoms and signs high in the epigastrium which were thought to be due to a perforated peptic ulcer. The upper abdomen was explored through a right rectus incision and no abnormalities were found. Postoperatively he got along fairly well but on the third or fourth day began to get short of breath and it became evident that he had a large right pleural effusion. Creamy pus was aspirated from the chest and he was transferred to the Hospital of the University of Pennsylvania for further care. On admission he appeared to be acutely ill but not desperately so. An air-fluid level in the lower portion of the mediastinum suggested the possibility that he had had an esophageal perforation.

A thoracotomy was performed the following day, five days after the first operation. There was thick creamy pus occupying the lower third of the right hemithorax and a perforation of the esophagus, one inch long, was found on the right lateral wall of the esophagus about three inches above the diaphragm. The esophageal defect was closed with the hope that healing might take place in spite of the intense inflammatory reaction which was present. The mucous membrane adjacent to the defect did not appear to be inflamed. The involved portions of the right lung were decorticated and all the fibrin clots and exudate were cleared out of the lower portion of the thoracic cavity. Two large drainage tubes were inserted and the thoracotomy incision was closed.

For three or four days postoperatively it appeared that the right lung remained well expanded with the aid of suction and that there was no further leakage from the suture line. By the end of the week, however, drainage through the thoracotomy tubes had increased and it was evident that the suture line had not held. A gastrostomy was performed for feeding purposes. The amount of drainage from the chest tubes varied but most of the time it was large in amount and much of the time gastrostomy feedings were noted in the drainage bottles. Protein hydrolysates and plasma were administered intravenously in large amounts. The electrolyte balance was maintained without great difficulty but the patient lost weight steadily. The possibility of isolating the thoracic esophagus from the cervical esophagus and stomach thereby diverting his salivary and gastric secretions away from the fistula tract was considered but by the time the decision was made to take such a step, the patient had deteriorated beyond hope for another procedure. He died about three and one-half weeks after the attempted suture of the esophageal defect. On post-mortem examination there was no evidence of undrained pus, but the drainage tract (empyema cavity) along the diaphragm was quite large and evidently accounted for the extensive protein loss. The esophageal defect was only one centimeter long.

*Comment:* This man appeared rather robust on admission but went downhill rapidly and died in three and one-half weeks despite adequate drainage.

The continuing soilage of the thoracic cavity with salivary and gastric secretions kept reactivating the empyema and mediastinitis with subsequent loss of large amounts of protein.

CASE 2.—P. K., a 41-year-old white man, experienced very severe epigastric pain followed shortly by collapse after eating a large dinner and vomiting on July 22, 1954. This was diagnosed as an instance of acute coronary occlusion and appropriate treatment for this diagnosis was given until the following day when chest films were taken and revealed a left hydropneumothorax. A No. 20 catheter was inserted into the left pleural cavity to relieve dyspnea and the patient was transported sixty miles to the Hospital of the University of Pennsylvania where a left thoracotomy was performed that evening, approximately twenty-four hours after the onset. He was in an extreme degree of peripheral vascular collapse and was in semicoma at the time of operation. His chances of survival did not seem good.

The left pleural cavity contained purulent material in addition to food particles, such as peas, in large amounts. The esophageal perforation was on the left lateral wall about three inches above the diaphragm. The area of perforation in the mediastinal pleura into the left pleural cavity was about four inches in length and the periesopahgeal tissues were severely inflamed, appearing black and necrotic in places. The entire left pleural cavity showed evidence of intense inflammation with erythema and engorgement of the subpleural blood vessels. Food particles and exudate were removed and the left pleural cavity was extensively drained. The patient survived this procedure and responded in a gratifying manner to antibiotics and general supportive therapy but it was soon evident that the closure of the esophagus was not successful. On the fifth postoperative day a Levin tube was passed into the stomach and gastrostomy feedings were given through the tube until the patient no longer tolerated its presence. It was removed and a gastrostomy was performed on Aug. 17, 1954, care being taken to pass the gastrostomy tube around the duodenal loop because of the experience in Case 1 of the feedings coming out through the esophageal fistula. This did not prevent leakage of significant amounts of gastrostomy feedings to the esophagocutaneous fistula, however, along with large amounts of saliva and gastric juice. He went steadily downhill with a course characterized by rapid weight loss and a toxic appearance despite supportive care by a large staff and an additional drainage procedure to ensure that no areas of inadequate drainage were present. It became evident that this man was going to die as the first patient had unless some radical step could be taken to exclude the fistula.

Finally, on Sept. 1, 1954, nearly six weeks after the spontaneous perforation of the esophagus, the esophagogastric junction was divided through a left subcostal incision and both ends were sutured. This resulted in considerable decrease in the amount of drainage from the fistula tract and the temperature came down somewhat. He still had persistent fever and considerable drainage and despite our hopes that it might be avoided, the lower cervical esophagus was divided about ten days later, with suture of the distal end and exteriorization of the proximal end as an external esophagostomy just above the left clavicle. The amount of drainage from the fistula tract then decreased in a most dramatic fashion and his temperature gradually returned to normal.

He left the hospital on Oct. 22, 1954, approximately three months after the onset of his illness, to gain strength and weight in preparation for esophageal reconstruction at a later date. Prior to discharge it was established that there was a bronchopleural fistula on the left which appeared to be largely responsible for occasional low-grade fever accompanied by wheezing and râles in the left lung. Because of persistence of these signs and symptoms and the threat believed to be inherent in persistence of the bronchopleural fistula, the remaining segment of the thoracic esophagus, including the original site of rupture, was excised on May 5, 1955, nearly ten months after the first operation. The esophagus was found to be distended with about 300 c.c. of purulent material identical in nature to the drainage material which had been persisting from the wound. The bronchial fistula was not visualized at operation but complete healing, following removal of drainage tubes, occurred a short time after this procedure. The patient continued to do well and did not return

until about six months later for esophageal reconstruction. In the meantime he had lived a comfortable and relatively normal life with his gastrostomy and external esophagostomy.

On Sept. 28, 1955, a jejunal loop prepared by the Roux-Y principle was brought up behind the sternum to the lower cervical region. There was no tension and the blood supply appeared to be entirely satisfactory after observation for one-half an hour. There were no difficulties following this procedure and three months later the cervical esophagus was anastomosed to the jejunal loop in the neck. Healing again was uneventful but the patient had intermittent diarrhea. This was overcome by connecting the new esophagus (jejunal loop) to the stomach, allowing his food once more to have a normal course through the stomach. He is now apparently restored to normal health.

CASE 3.—S. Z., a 40-year-old man, was brought to the Hospital of the University of Pennsylvania on Nov. 13, 1954, within a relatively short time following the typical symptoms and signs of spontaneous perforation of the esophagus. The esophageal rent on the left lateral wall, about three inches above the diaphragm and ¾ of an inch long, was closed by a meticulous suture technique about six hours after the onset. In spite of the favorable time factor, a virulent infection developed, including empyema of the right pleural cavity, and the suture line broke down with the development of a persistent fistula, as in the other 2 patients, despite adequate drainage of both pleural cavities. This patient presented the same picture of loss of gastrostomy feedings as well as large amounts of gastric and salivary juices through the fistula tract, rather rapid loss of weight, and increasing toxicity. The fistula-containing esophageal segment was excluded, as in the previous patient, by dividing the esophagogastric junction and the lower portion of the cervical esophagus seventeen and fifty-five days, respectively, after spontaneous perforation occurred. The fever subsided and the patient showed a steady weight gain.

Several months later, after he had gained five pounds, he was readmitted to the hospital and, on June 24, 1955, a jejunal limb was brought up to the neck retrosternally as previously described. The mesenteric vessels were not quite as long in this instance, however, and the color of the most cephalad portion of the jejunal limb did not remain good unless it was allowed to recede a short distance below the suprasternal notch. At the final stage, performed on Sept. 20, 1955, difficulty in approximating this end of the jejunum to the exteriorized upper esophageal segment was anticipated but the two ends came together quite readily after only a moderate amount of mobilization. There was a small amount of leakage from the suture line for a short time but this caused no difficulties and, at the present time, he is swallowing entirely satisfactorily with maintenance of adequate weight and a normal nutritional status, although his food does by-pass the stomach.

The drainage tract leading from the esophageal fistula in this patient finally healed on Nov. 25, 1955, and there has been no evidence of formation of a mediastinal collection or cystic dilatation of the esophageal remnant as evidenced by x-ray examination.

## COMMENT

The principle of exclusion has long been applied to the treatment of fistulas of other portions of the intestinal tract, particularly of the colon, following wounds or ruptured diverticulitis. It now seems reasonable to us that exclusion of a fistula of the lower thoracic esophagus is even more important than elsewhere in the gastrointestinal tract. The mediastinum and the empyema cavity are apt to be the site of very virulent infection because of the continuing soilage by pathogenic organisms and the enzymatic and chemical action of the saliva and gastric juice. These patients have become more rapidly depleted than those with gastric or duodenal fistulas, probably because of the large amount of protein lost from the infected pleural surfaces, plus the toxicity of the virulent pleural infection which is constantly kept

activated by additional organisms. In addition, there may, of course, be enormous losses of water and essential electrolytes of the saliva and gastric juices. Greater or lesser amounts of gastrostomy feedings also came out through the fistulous tract in spite of efforts to pass the gastrostomy tube around the duodenal loop in all three instances.

Hesitation in performing the exclusion procedure caused some delay in all 3 patients. When first considered, the permanency of procedures which completely exclude the involved esophageal segment, and the difficulties of later esophageal construction are impressive barriers. We have become convinced, however, that when a patient begins to slip with the characteristic signs and symptoms noted in these 3 patients, the radical course which we have outlined should be undertaken in spite of the evident disadvantages and prolonged discomfort which accompany the multiple operations. The fistula is excluded by dividing the stomach at its junction with the esophagus and suturing both ends. A gastrostomy is performed at the same time for feeding. The saliva is diverted away from the fistula by dividing the esophagus in the lower cervical area, closing the distal end, and bringing out the proximal end as an external cervical esophagostomy.

A number of reconstructive procedures are now available[2-4] and sufficient experience has accumulated so that they may be undertaken with reasonable confidence that the outcome will be successful. Stomach, jejunum, or colon may be used for esophageal replacement with the latter two being preferable to the former. It now seems feasible to reconstruct the esophagus behind the sternum in most instances rather than antethoracically, although a certain risk of necrosis of the segment which is advanced up to the neck is always present. With proper judgment, skill, and experience, this risk can probably be kept at a very low level.

If a jejunal loop, utilizing the Roux-Y principle, is brought up to the cervical esophagus, nutrition may not be adequately maintained in an occasional patient unless the substitute esophagus is anastomosed to the stomach.

Whether it is necessary to remove the patient's esophageal segment including the fistula has not been definitely established. Animal experiments suggest that it may not be necessary, at least in some instances.[5]

## CONCLUSIONS

1. Following spontaneous perforation of the esophagus, a persistent esophagocutaneous fistula may result, despite adequate drainage, if the fistula is not sutured or if the suture line breaks down.

2. Under such circumstances adequate drainage of the lower portion of the pleural cavity with application of suction may lead to healing of the fistula in some instances. In some patients, however, the fistula will persist in spite of adequate drainage.

3. When there is a persistent fistula, the patient has a virulent empyema constantly bathed with salivary and gastric juices and he becomes rapidly

depleted. Complete exclusion of the portion of the esophagus containing the fistula tract from the upper esophagus and stomach would seem to be a rational way to overcome the persistent mediastinal and pleural infection.

4. In 2 of our patients, total exclusion of the thoracic esophagus containing the fistula appeared to be lifesaving. The esophageal remnant containing the fistula had to be excised in one patient before the wound would heal. In the other, the wound has closed and the blind thoracic esophageal segment remains intact. Continuity of the upper intestinal tract was successfully restored in both patients by bringing up a Roux-Y jejunal limb, retrosternally. In one patient there was persistent diarrhea with the Roux-Y. This was overcome by dividing the jejunal limb and anastomosing it to the stomach.

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# Announcements

## THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

### Notice of Annual Meeting

The Thirty-seventh Annual Meeting of The American Association for Thoracic Surgery will be held May 4, 6, and 7, 1957, in Chicago, Illinois. Headquarters will be at the Palmer House.

### Requests for Hotel Reservations

These should be mailed directly to Mr. Edward Langford, Reservations Manager, Palmer House, Chicago. Please mention this Association, the type of accommodation desired, the date, and approximate hour of arrival and departure. If accommodations are desired elsewhere in Chicago, please communicate directly with the hotel of your choice.

### Thoracic Surgery Forum

The Thoracic Surgery Forum will be continued as a special session at the 1957 meeting. The Forum is primarily for the presentation of short papers on current thoracic research, experimental problems, anatomical studies, and modified or new surgical techniques. The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves the right to reject such papers, or to suggest their transferal to the Regular Program.

Papers at this session will be limited to ten minutes, including the showing of lantern slides or other illustrative material. At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper.

All Thoracic Surgery Forum papers will be published together in one issue of the JOURNAL. Maximum length: 3000 words without illustrations. If illustrated, an appropriate number of words must be subtracted for each cut used.

### Abstracts of Papers

Abstracts of all papers for presentation at the 1957 meeting must be received on or before Dec. 15, 1956, otherwise they will not be considered by the Program Committee.

Abstracts should be labeled "For Thoracic Surgery Forum," or "For Regular Program." The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper.

*Five, repeat, five* copies of *each* abstract must be sent to Miss Ada Hanvey, Administrative Assistant, The American Association for Thoracic Surgery, 600 South Kingshighway, St. Louis 10, Missouri.

Those on the program are reminded that papers presented at the meeting *must* be handed to the secretary immediately after their presentation. If they are not ready at that time there is a chance that they will not be published in THE JOURNAL OF THORACIC SURGERY.

### Motion Picture Session

Provisions have been made to show a limited number of motion pictures to be selected on a competitive basis. *The films themselves,* together with descriptive material concerning length of presentation, etc., must be received by Dr. Karl P. Klassen, The Ohio State University, Columbus 10, Ohio, before Dec. 15, 1956.

It is planned to run the motion pictures in a smaller room at the same time as the scientific sessions. If the films are well labeled, it will not be necessary for the author to be present for comment.

### Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec. 15, 1956, otherwise the application will be deferred for consideration until the 1958 meeting.

Applicants must be sponsored by three Active or Senior Members of the Association. In addition to the signatures on the application form, the sponsors will forward a *separate* letter concerning the applicant directly to:

Dr. O. T. Clagett
Chairman of the Membership Committee
Mayo Clinic
Rochester, Minn.

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year. The new letters of recommendation should also be sent to Dr. Clagett, the Chairman of the Membership Committee.

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